Introduction

1982 has been a significant year for the Ames Research Center with the continuing consolidation of the expertise at the Dryden Flight Research Facility into Ames overall programs. This annual report illustrates the breadth, depth, and substantial quality of Ames' achievements during the past year in the disciplines of Space Sciences and Applications, Life Sciences, and Aeronautics.

If you desire further information on any of the Ames research and technology programs, please contact the Research Assistant to the Center Director, Dr. David J. Peake, M.S. 200-10, NASA Ames Research Center, Moffett Field, California 94035.

C. A. Syvertson
Director

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NOTE: For additional information on any item, the Ames Staff member(s) named at the end of each item may be contacted. To call Ames North staff (where a four-digit extension number is indicated), commercial telephone users should dial 415-965- followed by the extension number (users with access to the Federal Telecommunications System (FTS) should dial 448- followed by the extension number). To call Ames Dryden staff (where a three-digit extension number is indicated) users should dial 805-258-3311 and ask for the extension (dial directly on FTS, 984-8 plus 3-digit extension).

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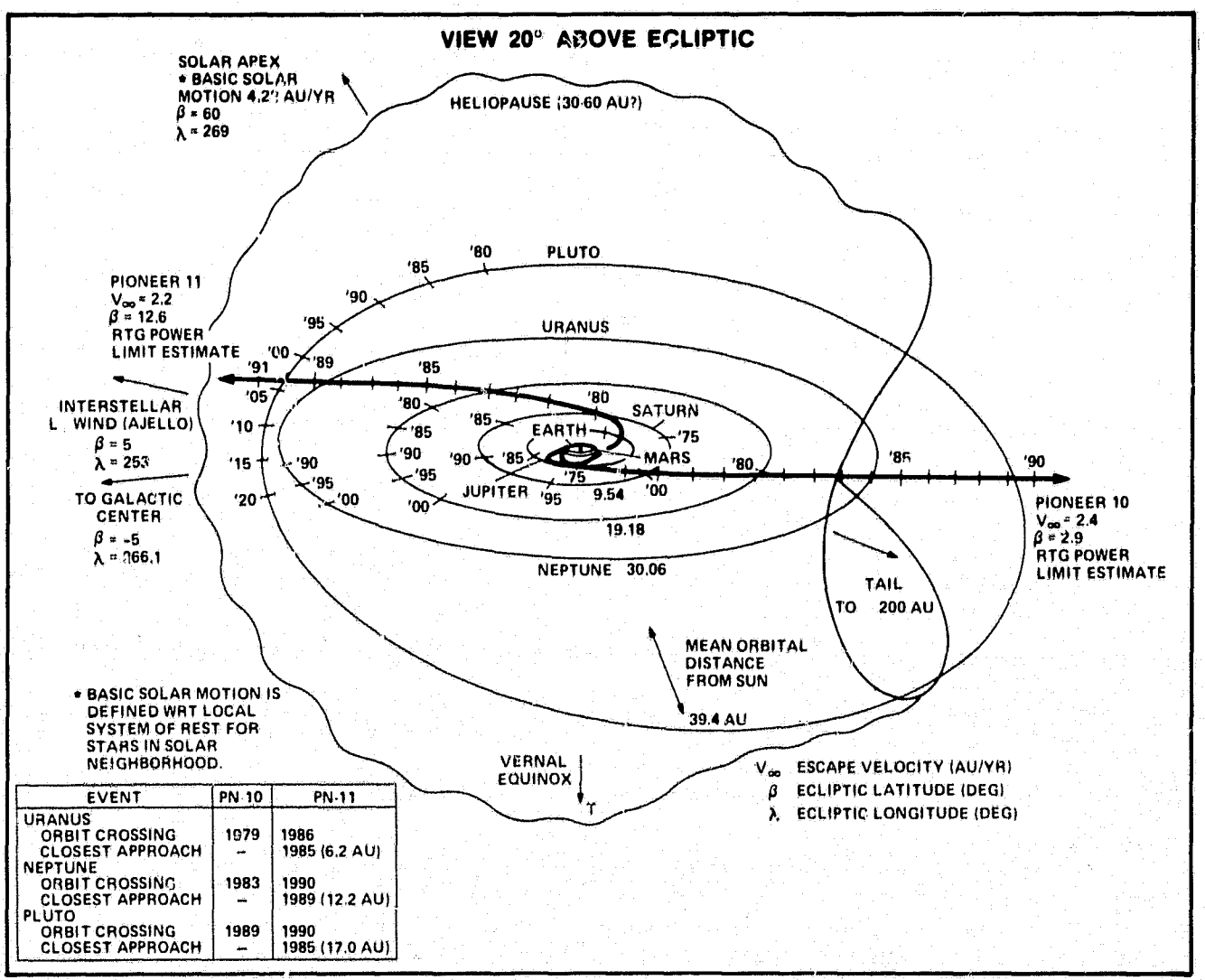
Space Science and Applications

Pioneers 6, 10, and 11

On December 15, 1982, the Pioneer 6 spacecraft begins its eighteenth year of operation. The spacecraft continues to transmit useful solar wind and cosmic ray measurements. This record of continuous scientific data transmission exceeds that of any other NASA spacecraft.

The Pioneer 10 spacecraft continues its outbound journey from the Sun at 2.8 AU per year. It is the most distant man-made object in our Solar System and in 1982 traversed space between 26.2 to 29.0 AU from the Sun. Data obtained from this spacecraft have totally changed previous models of the solar wind. The heliopause boundary has not yet been reached, and the temperature of the solar wind does not fall off adiabatically as previously predicted. High-speed streams in the solar wind cease to exist beyond approximately 10 AU. Pioneer 10 continues on its escape of our Solar System in a direction opposite that of the Sun's motion through the Milky Way Galaxy. The extreme distance from the Sun now places Pioneer 10 in a unique position to search for the existence of gravity waves and a trans-Neptunian planet.

Pioneer 11 is presently leaving the Solar System at a radial velocity of approximately 1.9 AU



EVENT	PN-10	PN-11
URANUS		
ORBIT CROSSING	1979	1986
CLOSEST APPROACH	–	1985 (6.2 AU)
NEPTUNE		
ORBIT CROSSING	1983	1990
CLOSEST APPROACH	–	1989 (12.2 AU)
PLUTO		
ORBIT CROSSING	1989	1990
CLOSEST APPROACH	–	1985 (17.0 AU)

Pioneer 10 and 11 trajectories and orbits of Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto

per year in a direction opposite to that of Pioneer 10. The Imaging Photopolarimeter Instrument is making observations to complete a background starlight map of the entire day.

These two spacecraft provide our first large-scale examination of the Sun as a star with its surrounding gas and dust. The spiral structure of solar wind particles and fields is being measured as is the incursion of interstellar particles into our Solar System. Both spacecraft continue to measure the cosmic ray gradient and modulation in order to determine the origin of cosmic rays and their interaction with our heliosphere. These cosmic rays, which penetrate both the heliosphere and the Earth's magnetic shield, account for most of the low-level radiation received by humans on Earth. The presently available deep space network (DSN) tracking systems will be able to receive data from Pioneers 10 and 11 to measure properties of the heliosphere out to at least 52 AU.

(P. Dyal, Ext. 6545; R. Fimmel, Ext. 6456)

Pioneer Venus

The Orbiter is continuing in an extended mission phase (Phase II) characterized by slow variation of orbital parameters caused by the Sun's gravity. By 1986 periapsis altitude will reach its maximum at 0.4 Venus radii, and the axis of the orbital ellipse will have rotated into a plane parallel to the ecliptic, owing to the gravitational influence of the Sun. The Orbiter's altitude will again decrease, such that by 1992 low-altitude radar measurements can again be made. The slow variation of orbital parameters, particularly periapsis altitude and latitude, which occur naturally during Phase II, opens new regions of the Venus environment for exploration.

The scientific results of Phase II of the Orbiter extended mission, up to October 1982, are as follows:

1. The altitude of the ionopause is observed to respond sensitively to the solar wind.
2. Ions are observed flowing from the Venus dayside to nightside, and modeling of the flow suggests that this mechanism may account for the maintenance of the nightside ionosphere.
3. The possibility that lightning is associated with high-altitude topography has been further supported by plasma-wave data obtained during nighttime passages over the eastern end of Aphrodite.
4. Stratospheric haze, which appears dense relative to the 1974 Mariner encounter, appears to have begun to diminish in recent months.

(L. Colin, Ext. 5519)

Solar System Plasma Studies

The Pioneer 10 plasma analyzer continues to monitor the solar wind at 29 AU, well beyond the orbit of Uranus. The heliospheric boundary has not yet been reached; shocks from solar flares are still observed at the distance of Pioneer.

The Pioneer Venus plasma analyzer has established the presence of a filamented flapping wake far behind the planet, probably much like a comet tail. The wake includes atmospheric gas that has been scavenged by the solar wind blowing past the planet.

New extensions of the theory of large-amplitude hydromagnetic waves and turbulence have been accomplished.

(A. Barnes, Ext. 5506)

Planetary Ring Studies

Planetary rings are under study by scientists and NRC associates in the Ames Space Science Division, along with university collaborators. Ongoing analysis of the Voyager images of Saturn's rings has led to discoveries of spiral waves of two different types. The waves are similar in their physics to those thought to cause structure of spiral galaxies, but are more tightly wrapped (like a watch spring) and are "forced" by strong resonances with Saturn's main satellites. Both horizontal (density) waves and vertical (corrugation) waves have been discovered. Also, new results strongly support the existence of moonlets embedded in an as-yet-unexplored gap in the A ring. Sophisticated image-processing

facilities developed for ERTS and LANDSAT imagery are being used to further analyze the Voyager images of Saturn's and Jupiter's rings. Theoretical work is focusing on the physics of gravitational and collisional effects in particle disks, including the behavior of resonances, linear and nonlinear wave damping, and the effects of a particle-size distribution on the viscosity of the disk. The viscosity is crucial to understanding both the "thousand ringlet" structure in the B ring, which may be due to a viscous instability process, and the evolution of the disk as a whole. Many of the processes which are seen occurring today in Saturn's rings were probably of significance in the evolution of planets from the protoplanetary nebula.

(J. Cuzzi, Ext. 5530)

Jupiter Probe Heat Shield

Design and fabrication of the heat shield required to protect the Galileo Probe Spacecraft from the intense heat generated by entry into the Jovian atmosphere were completed in 1982. The carbon phenolic forebody heat shield and the phenolic nylon afterbody heat shield protect the probe's science payload from the heat flux as high as 40 kW/cm^2 resulting from the entry velocity of more than 100,000 mph. The heat-shield materials were tested in specially developed arc-jet and laser test facilities by the Thermo- and Gas-Dynamics Division, and the selected design was verified by detailed comparison with benchmark analytical models which accurately simulate the complex physical and chemical phenomena of high-speed atmospheric-entry heating.

(J. Sperans, Ext. 5706)

Airborne Infrared Astronomy

In FY 1982, the C-141 Kuiper Airborne Observatory (KAO) made 62 astronomy research flights for 465 flight hours. Twenty-four investigator teams participated in the program, seventeen from universities and seven from NASA centers; all but one of those teams were supported by NASA grants and RTOP's. Major areas of research during the past year in the infrared airborne astronomy program included: the planets, particularly Jupiter and the outer planets, Uranus and Neptune; spectroscopic identification of many atomic ions and molecules found in the gas and dust clouds of our own galaxy where stars are being formed; and photometric mapping of other galaxies. This progress is due in large part to the significant advances in infrared detectors and instrumentation that the KAO users have made.

(R. Cameron, Ext. 5338)

Infrared Radiation From Supernovae

Supernovae are massive stellar explosions in which heavy elements are synthesized and returned to the interstellar medium. The discovery of isotopic abundance anomalies in meteoritic grains has led to the suggestion that these anomalous grains condensed in the material ejected in a supernova explosion and were incorporated into the material of the solar system as it formed. This idea can be tested by searching for infrared radiation from supernovae which could be attributed to thermal emission from dust formed during the explosion.

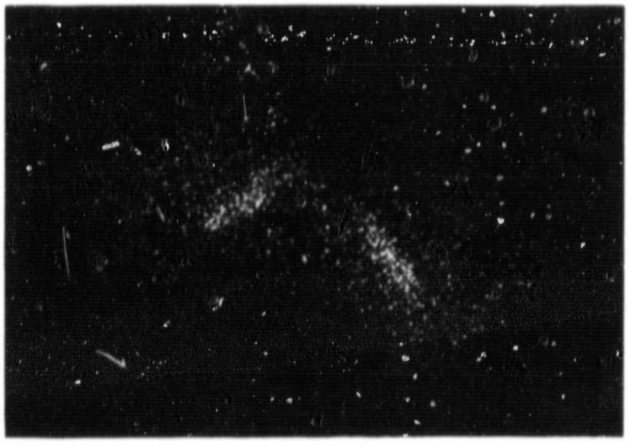
Observations carried out by Ames Research Center astronomers at the NASA Infrared Telescope Facility, in collaboration with astronomers from Hawaii and from the Goddard Space Flight Center, have provided evidence for dust formation in supernovae. Infrared radiation at 10 μm has been detected from a knot of gas in the Cassiopeia A supernova remnant in our Galaxy. This knot was known from optical observations to have peculiar chemical compositions and to be moving at a velocity of several thousand kilometers per second; these facts suggest that the knot was ejected from within the exploding star. The bright supernova which occurred in October 1980 in the nearby galaxy NGC 6946 was monitored at infrared wavelengths throughout the following year. In May 1981, the supernova exhibited strong radiation at wavelengths between

2 and 4 μm, suggesting the onset of dust condensation. Subsequent observations showed that the infrared excess persisted until October 1981, implying continuing dust condensation as the ejected material cooled.

(M. Werner, Ext. 5101)

Numerical Experiments on the Dynamic Evolution of Galaxies

Environmental effects on galaxies in clusters of galaxies have been investigated using a three-dimensional, large n-body code on the large-scale computers at Ames Research Center. The numerical experiments indicate that influences from a cluster environment appreciably change the internal dynamics of individual galaxies in the cluster. These experiments indicate that the observable rotation is reduced so that, initially, rapidly rotating galaxies are slowed to rotational velocities compatible with observations for elliptical galaxies. In addition, the rotation pattern is affected such that the galaxies tend to align pointing toward the cluster center. This pattern of alignment has been observed.



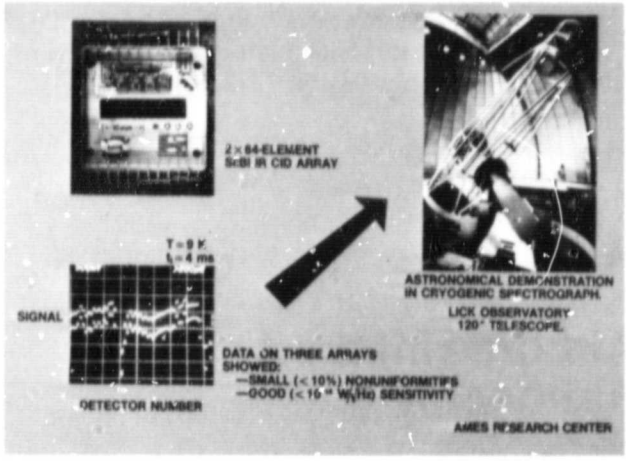
Numerical experiment of interacting disk galaxies

Collisions and merging of disk galaxies embedded in halos have been investigated using the same experimental method. The interpenetrating collisions lead to a violent disruption of the disk galaxies. A variety of responses has been found for the disks ranging from stretched out, nearly linear forms to rapidly propagating ring-like patterns. The galaxy collisions studied are highly inelastic and lead to eventual merging into one galaxy. The final galaxy in these cases is a prolate, barlike galaxy looking much like an elliptical galaxy. There is observational evidence that this may be the mechanism responsible for the formation of giant ellipticals in clusters. The numerical experiments are in agreement with such a suggestion. The important conclusion to be drawn from these experiments is that galaxies in a cluster respond to, and are affected by, their surroundings in significant, observable ways.

(B. Smith, Ext. 5515)

Extrinsic Silicon CID Linear Detector Arrays for Infrared Astronomy

To evaluate the performance capabilities of linear, extrinsic silicon detector arrays for infrared (IR) astronomy, 2- by 64-element Aerojet Electro-Systems Si:Bi charge-injection device (CID) arrays were developed for use in a dispersive spectrometer. Three arrays, each with 0.18-mm (7-mil) pixels on 0.21-mm (8-mil) centers, have been characterized at Ames under the "moderate" background levels to be experienced



Characterization and demonstration of linear integrated IR array.

in ground-based astronomical demonstrations. The laboratory results indicate an average, responsive quantum efficiency of about 22%, a read noise of about 300-rms electrons, and non-uniformities less than 10% of the average at an operating temperature of 9 K. This level of sensitivity is comparable to that of the best discrete IR detectors available today.

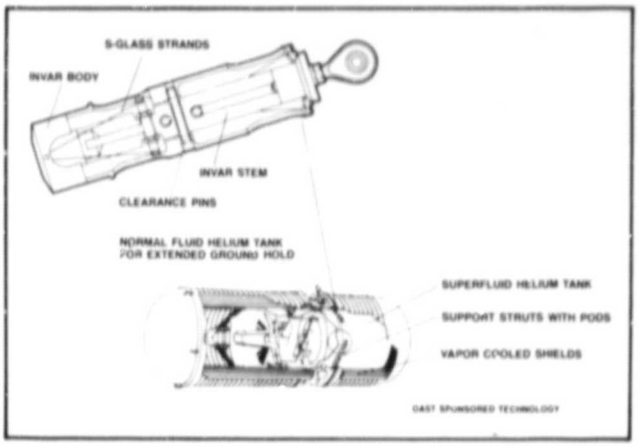
Following supplemental tests under the low-background levels required for the Shuttle Infrared Telescope Facility (SIRTF), the best array will be used in the first spectroscopic observation using an integrated IR array. An existing cryogenic spectrograph has been modified to accept the array, and a state-of-the-art microcomputer data system has been built for the array. The 3.0-m Shane telescope on Mt. Hamilton will be used for the observation in collaboration with Lick Observatory astronomers.

(H. Lum, Ext. 6544; C. McCreight, Ext. 6549)

Passive-Orbital-Disconnect Struts for Long-lifetime Helium Dewars

A feasible spaceborne technology concept called Passive-Orbital-Disconnect Strut (PODS) has been developed for potential application in a launchable helium dewar with a 3-year lifetime. PODS is designed to reduce the parasitic heat loads inherent in tank supports, wire leads, and multilayer insulation representing approximately 67, 17, and 14%, respectively, based on the Infrared Astronomical Satellite (IRAS) project. In orbit the stem is suspended in the body by "S"-glass strands. These strands form a low thermal-conductance path. During launch the strands stretch until the stem contacts the clearance pins which in turn accommodate the launch loads. The change from orbital to launch configuration is completely passive and repeatable.

The PODS technology is expected to reduce the orbital support conductance by more than an order of magnitude over current tension band supports. As a result, this lower support conductance will reduce the total dewar weight by half for the same 3-year-lifetime requirements. A preliminary design of the dewar has been



Long-lifetime helium dewar.

analyzed thermally and structurally; and a system design, including system weights, thermal performance, and performance sensitivities, has been defined. Potential applications also include the cryogen tank supports for the space station and the orbital-transfer vehicles.

(H. Lum, Ext. 6544; P. Kittel, Ext. 6525)

Biogenic Hydrocarbons Emissions Inventory Project

While it is not true that trees cause pollution, it is known that hydrocarbon emissions from natural vegetation contribute to the production of ozone. Moreover, ozone, which is formed when nitrogen oxides and hydrocarbons combine in the presence of sunlight, is a major variable in air quality planning models. Ames Research Center and the Association of Bay Area Governments (ABAG) have conducted a study to investigate natural sources of hydrocarbon emissions to determine if they are a primary mission factor in models designed to predict pollution levels in the San Francisco Bay Area.

This study is particularly interesting in that it utilizes Landsat digital data to develop land cover maps and then goes one step beyond to extract additional information. The land cover classification was employed to assess the areal extent of known land cover types to which hydrocarbon

emission rates were assigned on the basis of empirical studies. The resulting data were integrated into an existing geographic information system for input into the Livermore Regional Air Quality (LIRAQ) model. While air-quality modeling efforts using the emissions inventory are still ongoing, initial results are promising and the information is being applied to other environmental planning problems.

(D. Lumb, Ext. 5900)

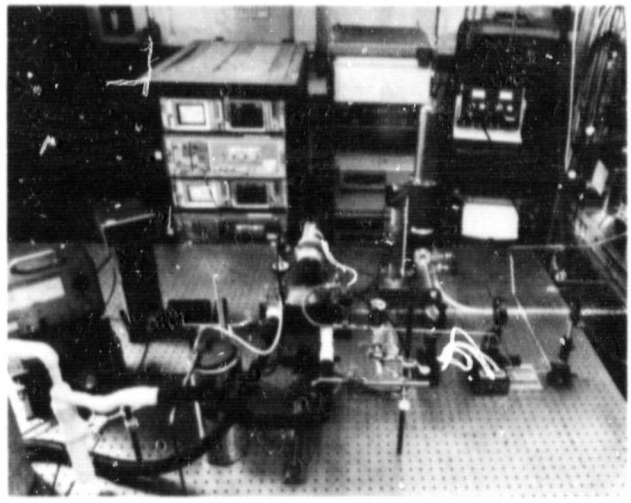
Climatic Effects of Volcanic Particles

The massive El Chichon volcanic cloud is being intensively studied from a variety of airborne platforms managed by NASA's Aerosol Climatic Effects (ACE) program. Subsequent to the detection of sulfur gases and ash particles in the stratosphere from the Mexican volcano in early April, the cloud's physical, chemical, and radiative properties have been sampled in situ by experiments carried by a NASA U-2 aircraft, vertically probed by experiments on a University of Wyoming balloon, and remotely sensed by experiments flown on NASA's Convair 990 aircraft. Scientists from a number of universities, NASA centers, and other government agencies and research centers are in charge of these experiments. The data collected from these various airborne platforms, in conjunction with data obtained from the ground and from such satellites as SME, will provide a comprehensive data set for evaluating the effects of the El Chichon cloud on temperature and wind patterns in the stratosphere and troposphere. The El Chichon cloud consists primarily of submicron-sized sulfuric-acid particles and micron-sized ash particles that are coated with sulfuric acid. A small amount of salt (sodium chloride) particles is also present. In the northern tropics, the cloud has had an optical depth of about 0.25 from April through August 1982. Thus, about 25% of vertically incident sunlight is intercepted there by volcanic particles, providing impetus to careful measurement of its potential impact on the Earth's climate. These observations and their theoretical analyses will provide a better understanding of the climatic impact of massive volcanic clouds and may provide a good geophysical experiment for testing climate models.

(J. Pollack, Ext. 5530)

Photodiagnostic Instrumentation

A remote laser spectroscopic technique has been developed that can simultaneously and instantaneously measure fluctuating temperatures and densities in a low-temperature turbulent nitrogen flow. The method relies on laser-induced fluorescence from two-photon absorption in trace concentrations of nitric oxide (NO) seeded into the nitrogen background gas. Temperatures in the range between 150 and 500 K have been measured in a nonflowing cell with errors less than 2%. Spatial resolution of the measurements is typically less than 1 mm. An absolute temperature and relative density are obtained following each laser pulse. Thus, mean values and their probability distribution about the mean are obtained for each variable. Since both temperature and density are measured simultaneously from the same volume, pressure and its fluctuations may also be inferred using the perfect gas



Photodiagnostic instrumentation

equation. Given suitable optical access, measurements can be obtained from submillimeter volumes anywhere in the flow field. Accuracy is limited only by the efficiency of the fluorescence collection optics and the concentration of NO in the flow. Useful measurements in supersonic wind tunnels are expected to require collection optics with an f number less than 2 and nominal NO concentrations of 300 ppm.

(J. Arnold, Ext. 6209)

Properties of Molecules

The theoretical determination of the physical properties of molecules and atomic clusters from first principles continues to produce important results. Major advances in the theoretical description of atomic clusters have been achieved due in large part to the availability of the CRAY 1S computer. Building on knowledge obtained at Ames in recent years for the electronic structure of metal atoms and diatomic molecules, studies on metal dimers and diatomic hydrides and oxides have been completed and studies of larger metal clusters are under way.

The diatomic molecules studied include the transition metal dimers (Sc_2, V_2, and Cu_2) and hydrides (TiH, VH, CrH, MnH, and FeH), and the alkaline earth oxides and fluorides (MgO, CaO, and SrF). These results have led to a detailed picture of metal atom bonding, including elucidation of the unique properties of the transition metals. Theoretical studies of larger clusters (e.g., Mg_4, Ca_4, Mg_{13}, Ni_5, Cu_5, and Fe_9) have provided insight as to how the bonding changes between small clusters and the bulk. Further studies of Ni_5O, Ni_9CO, and Al_9CO have led to an improved understanding of chemisorption — the interactions of gaseous molecules with metal surfaces. Finally, studies of iron-hydrogen clusters (Fe_nH, $n < 9$) are helping scientists understand the forces that dissolved hydrogen atoms exert on iron lattices.

Other theoretical studies have concentrated on determining the spectroscopic properties of small molecules found as trace species in the atmosphere and in combustion systems. The computed spectroscopic parameters are used by other researchers in the design of diagnostic techniques to monitor the concentrations and/or temperature of these species. Molecules studied have included O_3 (atmospheric application), OH (atmospheric and combustion applications), and C_2H (combustion applications).

(J. Arnold, Ext. 6209)

Atomistic Simulation of Materials

The results of an atomistic simulation of slip formation and crack propagation have been obtained. The model used in this study consisted of a two-dimensional triangular lattice (which contained 400 or more particles) with a uniaxial load exerted on it. Each particle was treated discretely. This model produced results that are consistent with those from macroscopic theory. In particular, the results indicate that slips occur predominantly on rows with higher density of atoms (i.e., along the close-packed rows). These results also illustrate the involvement of dislocations in the slip-formation process. Simulations were performed with perfect crystals and crystals containing point defects. In all cases studied, the systems with point defects experienced slip formation at smaller strains than did the corresponding perfect crystals. Vacancies located near the surface move to the surface and trigger slip formation from that location. However, vacancies in the interior of the crystal move to the surface during the slip process which occurs along a plane containing the vacancy.

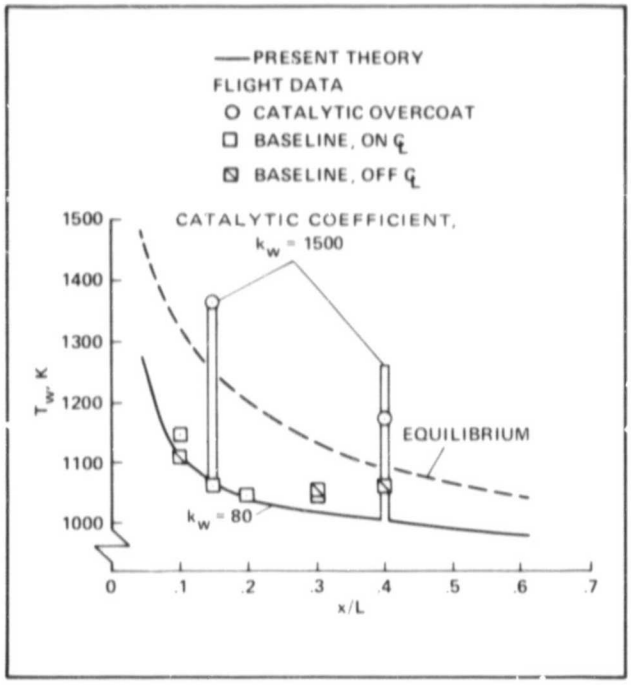
An additional computer simulation of the behavior of atoms near a crack tip has successfully predicted steady-state crack propagation speeds in metals. This was accomplished by developing a technique which effectively allows an atomistic model to move through a metal crystal at the same speed as the crack tip. The theoretical results for crack propagation speeds for steels agree well with the experimental values.

The information obtained from these studies is providing a better understanding of the various mechanisms involved in the fundamentals of material strength and failure.

(J. Arnold, Ext. 6209)

Orbiter Experiment Program

Two thermal protection experiments successfully flown on STS-2 and STS-3 were the Catalytic Surface Effects and Tile-Gap Heating experiments. The Catalytic Surface Effects Experiment demonstrated, for the first time on a flight vehicle, that the noncatalytic nature of the heat-shield coatings on the Shuttle substantially reduces the heat flux. Demonstration of this phenomenon will influence the design of all reusable reentry vehicles to be built in the future.



Spatial surface temperature variation on Shuttle windward centerline for flight STS-2, 450 sec from entry interface

New heat-shield materials will be required to be noncatalytic if possible. Data from the tile-gap heating experiment are now being used to evaluate the effects of gaps and steps on convective heating in the gaps between Shuttle tiles. These data will help solve Shuttle heating problems and influence heat-shield design of future reusable entry vehicles.

(H. Larson, Ext. 5369)

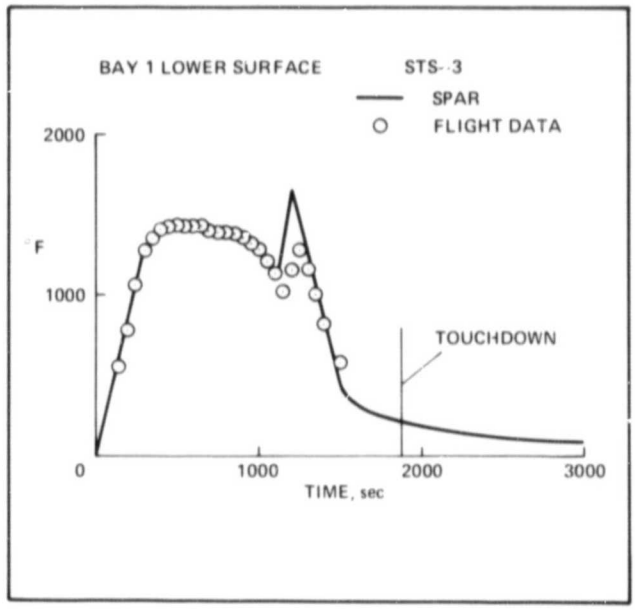
Hot Structures Research

The efficient design of high-speed aircraft and space-transportation vehicles depends heavily on the prediction of the structural response to aerodynamic heating. A joint effort between Johnson Space Center, Langley Research Center, and the Ames Dryden Flight Research Facility was established to improve the technology in this area.

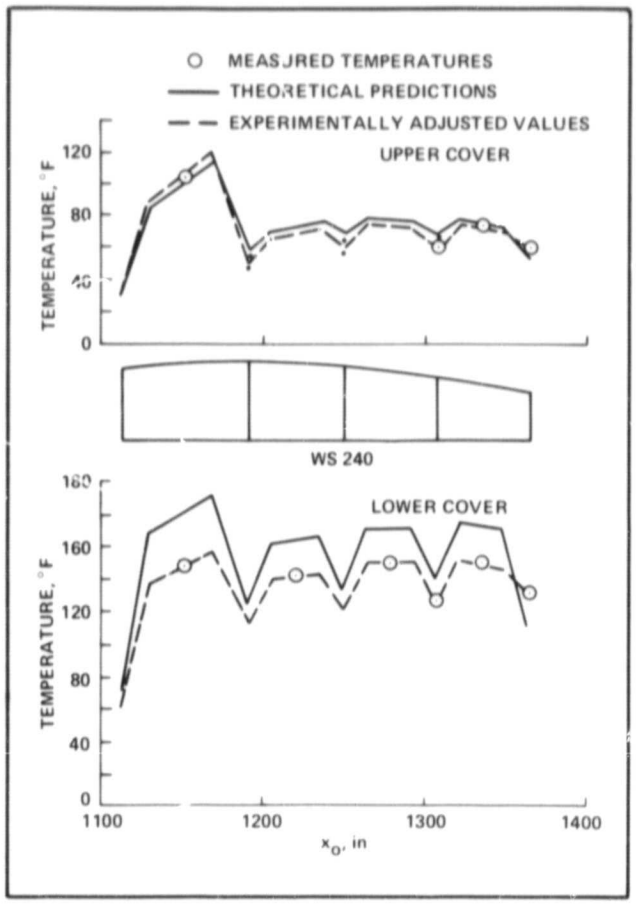
Orbiter Vehicles 101 and 102 were instrumented with strain gages and calibrated for load measurement through a joint Johnson Space Center/Dryden effort, and SPAR computer heat-transfer models for the instrumented Orbiter Wing cross sections were generated at Dryden. Conventional two-dimensional thermal stress models of these cross sections and a SPAR full wing structural model were also generated at Dryden.

In 1982 data for Orbital Flights STS-2, 3, and 4 were received and processed. Predicted and measured results for temperature time history, temperature chordwise distributions, thermal stress, and loads for the midspan wing station were charted. Although the general agreement was fairly good, significant differences were apparent.

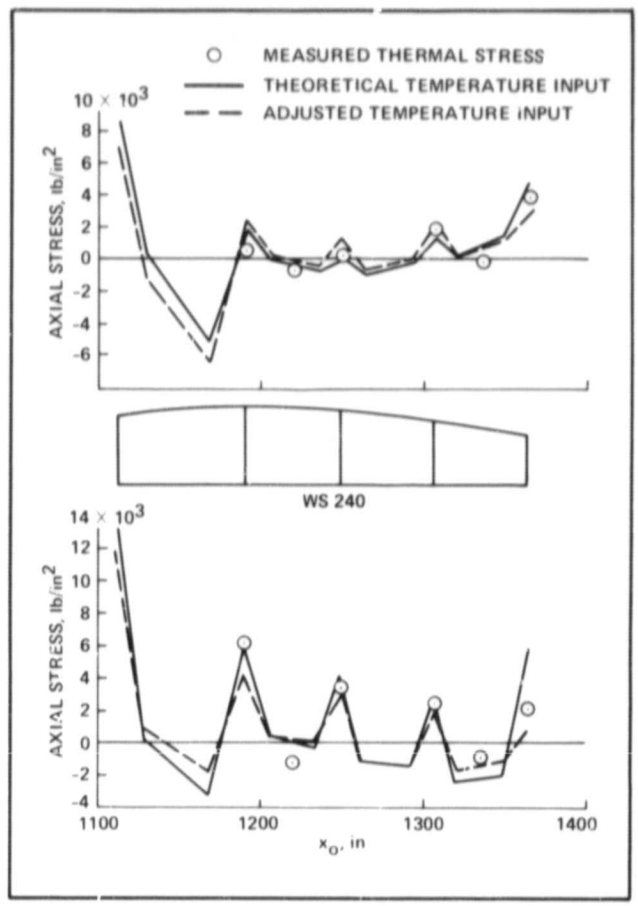
(A. Carter, Dryden Ext. 453)



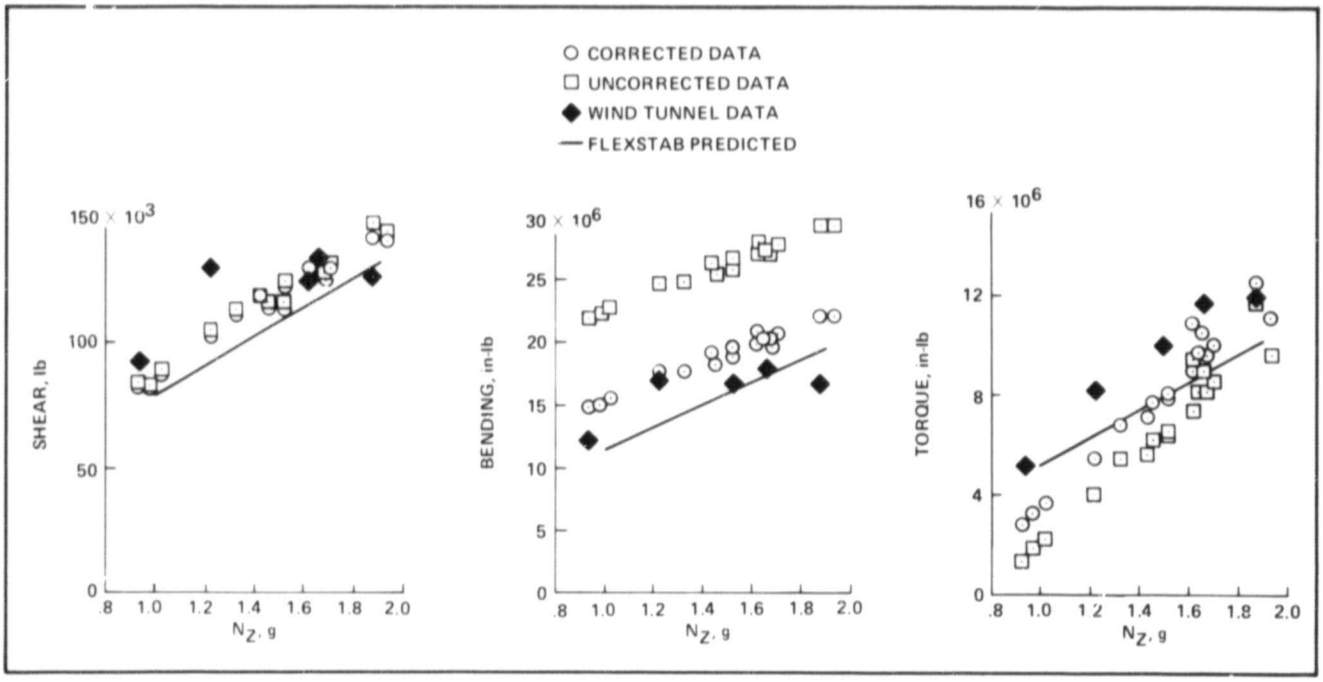
STS-3 TPS temperature time-history at Wing Station 134.



Temperature measurements at wing station 240



Thermal stress at wing station 240

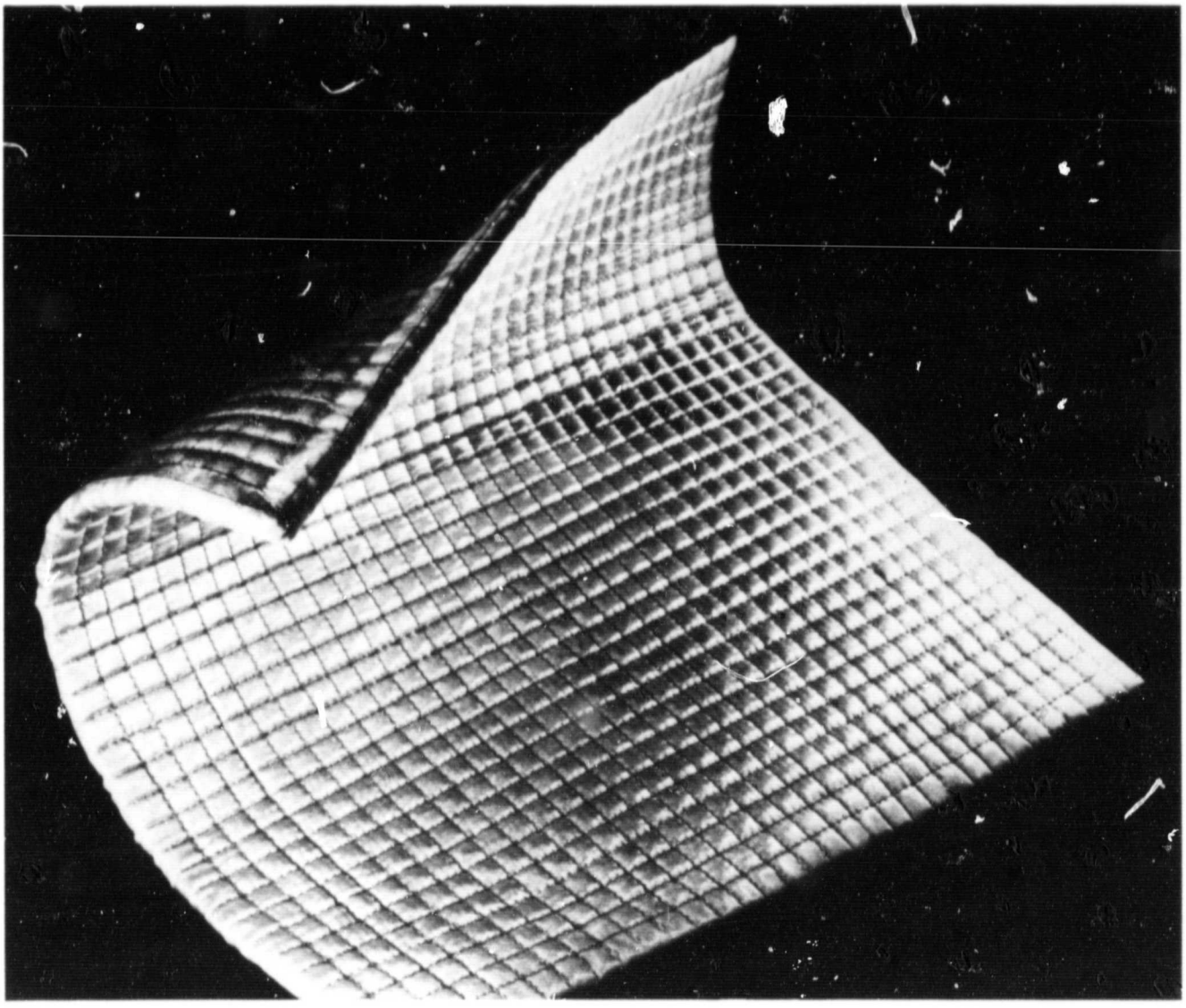


Loads at wing station 134, Mach 0.82 turn

Advanced Heat Shield Materials for Space Shuttle

Advanced Flexible Reusable Surface Insulation (AFRSI) was installed on the Orbiter Maneuvering System Pods on Challenger. Certification tests are nearly complete for both AFRSI and FRCI-20-12, the new high-strength RSI. Parts have been delivered to Rockwell's Palmdale plant by Manville Building Materials Co. and Lockheed Missiles and Space Co. for installation on Orbiter Discovery. AFRSI will cover over 2000 ft^2, replacing nearly all LRSI tiles, and the FRCI will replace about 3000 LI-2200 silica tiles. AFRSI will be used in areas where temperatures exceed 1500°F even though the material was adopted on the basis of a 1200°F maximum-use temperature. Other Ames-developed high-temperature materials (LI-2200, Ames Gap Filler, and Reaction Cured Glass Coating) have performed successfully on STS-1 through -4.

(H. Larson, Ext. 5369)



Advanced flexible reusable surface insulation.

Life Science

Physiological Responses of Women to Simulated Space Flight

Over 80 healthy men and women have been studied under simulated Shuttle flight stresses as part of the Operational Medicine program to develop selection criteria for Space Shuttle crews. In the near future, astronauts and mission specialists from all adult age groups will be chosen to perform operational tasks and conduct experiments in space. This past year the oldest group of subjects, nine women between the ages of 55 and 65, underwent 10 days of bedrest to simulate weightlessness, followed by tests for orthostatic tolerance to test the ability to maintain blood flow to the brain without fainting. These tests included application of lower body negative pressure (LBNP) at the level of -50 mmHg suction for 15 min and acceleration of +1.5 and +2 g, simulating reentry stresses.

Results compared to previous tests with 55- to 65-year-old men, demonstrated consistently higher LBNP and acceleration tolerances for the males. An analysis of ultrasound echocardiograms during LBNP indicated that smaller heart volumes in older females may contribute to their lower tolerance. In general, an inflated anti-g suit of the type worn by Air Force pilots protected all subjects during acceleration exposures by reducing their heart rates and elevating their blood pressures. This countermeasure did not prove totally effective in all cases. After bedrest during exposure to +1.5 g, two women became hypotensive with basal systolic blood pressures less than 95 mmHg (typical systolic is 120 mmHg). During exposure to +2 g, four women became hypotensive, and two experienced greyout. One man out of eight in the older age group had greyout during exposure to +2 g. Following bedrest, acceleration tolerance of unprotected subjects at +3 g decreased significantly by 59% in the women, and by 50% in the men.

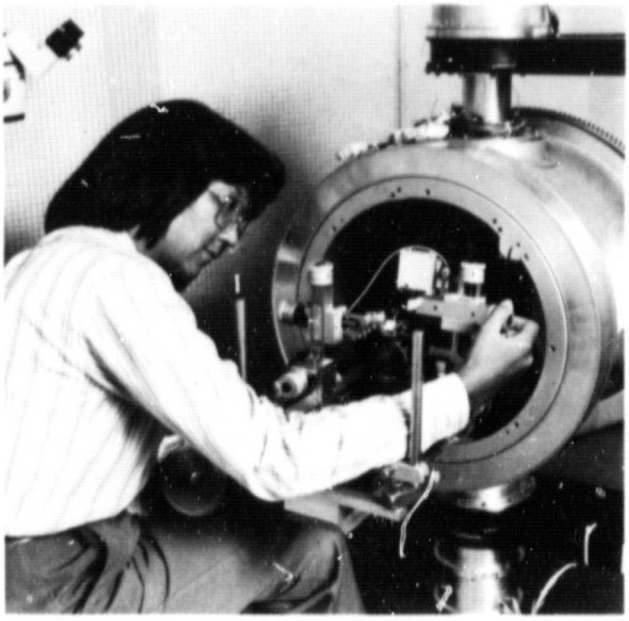
Woman bedrest subject ready for testing of orthostatic tolerance in 20-g centrifuge.

These findings point to the significant loss during bedrest of cardiovascular reserve activity, which is the capacity to maintain blood flow and pressure. The results further indicate the involvement of the nervous system in signaling flow distribution and blood pressure, as well as possible effects in the heart and blood vessels themselves.

(D. Goldwater, Ext. 5749)

Vestibular Research Facility

On the basis of space motion sickness problems encountered on American and Soviet spaceflights, the Vestibular Research Facility (VRF) program was established to develop unique, multipurpose instruments for use in vestibular research. Considerable progress has been made this year toward



Preparation of equipment prior to experiment run on the ground version of the VRF flight rotational system.

implementing this research program at Ames. A ground version of the flight rotational system has been built which provides unique capabilities for advanced vestibular research. This system provides for a complex set of motion stimuli while simultaneously providing a pseudo-gravitational centrifugal force.

In a series of tests, investigators from the University of Texas, Galveston, measured single, vestibular neuron electrophysiological responses of small mammals under controlled acceleration profiles. The investigators implanted the animals in their laboratories. The animals were then tested at Ames using the ground version of the flight rotational system. Mathematical models were used to implant electrodes in the same neuronal area as used for the earlier baseline studies. The information gathered is leading to a more complete understanding of the motion-sensing organs.

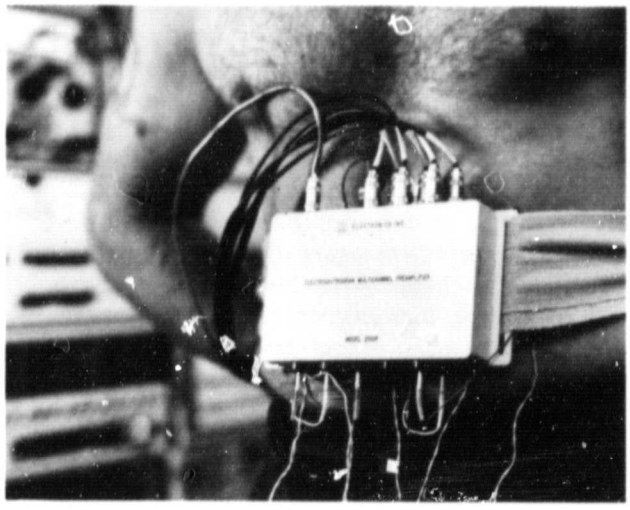
Because of its unique capabilities, the ground-based facility is being made available for use by the scientific community before proceeding to flight programs.

(R. Mah, Ext. 6538)

Biofeedback-Style Training to Overcome Space Motion Sickness

Techniques involving autogenic (or self-induced) therapy combined with biofeedback training have cured motion sickness symptoms in 80% of the subjects studied by both NASA and the Air Force. Autogenic Feedback Training (AFT) teaches the individual to control various vital signs by providing continuous, bioelectric monitoring of the body. Since AFT provides one of the most promising treatments for space motion sickness, it is scheduled for use on the upcoming Spacelab 3 flight.

Formulating a comprehensive picture of the physiological and psychological processes of motion sickness is one of the goals of the Biomedical Research program. The relationship between gastric activity and other physiological parameters was researched in collaboration with the University of California at San Francisco and in consultation with the Max Planck Institute, Munich, Germany. During 1982 an electrogastrograph compatible with biofeedback techniques was designed and fabricated. Preliminary results of tests on 26 men and women in coriolis (rotating



Electrogastrograph developed to be compatible with biofeedback training for astronaut control over motion sickness symptoms

chair) indicate that the electrograph provides a very sensitive index of the onsets of motion sickness.

Medical electronic instruments and body parameters new to AFT techniques have been studied to improve its effectiveness. The feasibility was established for computer control of an inflated blood pressure cuff, integrated for the individual in a biofeedback loop. A tiny photoplethysmograph transducer glued to the fingernail is being used to measure blood volume as yet another parameter which can be presented to the subject and improve the efficiency of AFT.

(P. Cowings, Ext. 5724)

Animal Models in Space Sickness Research

The space motion sickness program at Ames functions as a focus for a wide range of collaborating institutions, including the Massachusetts Institute of Technology, University of California at Los Angeles, Ohio State University, Rockefeller University, Tulane University, the University of Chicago, the University of North Carolina, the University of Pittsburgh, and the University of Texas. The Biomedical Research Division, in cooperation with investigators from Wright State University and San Jose State University, has examined the responses of squirrel monkeys, cats, rats, and mice to establish suitable models for the study of space motion sickness.

Our basic research focused on the causative factors of motion sickness, as well as possible countermeasures. Test results support the hypothesis that a substance in the cerebral spinal fluid may trigger vomiting in response to motion, since blocking the flow of cerebral spinal fluid to the chemoreceptive trigger zone in the brain eliminated emesis in cats that were previously susceptible to motion sickness. In addition, drug studies with cats, both susceptible and resistant to motion sickness, suggest that dopamine pathways in the body are involved in producing motion sickness. Droperidol, a dopamine antagonist, is an effective antimotion sickness drug in cats.

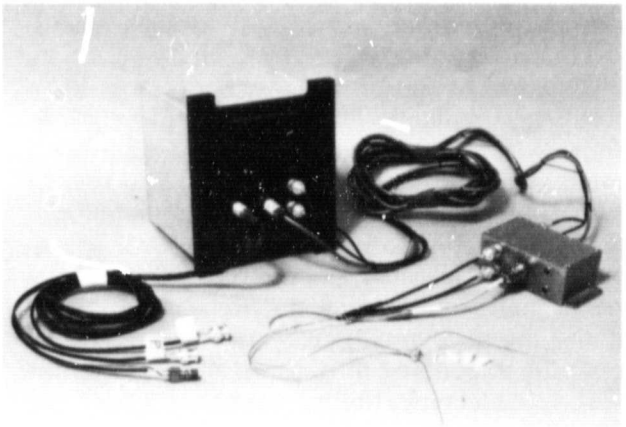
In studies with squirrel monkeys, the juveniles were more susceptible than adults to motion sickness induced by rotation and linear acceleration. These results corroborated known results in studies with humans. Also, sickness was prevented in restrained squirrel monkeys, which suggests that postural control plays a role in the development of motion sickness.

Motion stimuli, which cause motion sickness symptoms in humans and other animals with an emetic reflex, also caused conditioned taste aversion, feeding suppression, and drinking suppression in rats and mice. The magnitude of these effects depend on the severity of the stimulation used to induce motion sickness. These results suggest that the rat and mouse could be used for certain types of studies in motion sickness, even though these species do not have an emetic reflex.

(N. Daunton, Ext. 6245)

Cardiovascular Responses in Nonhuman Primates

Studies of circulatory changes during weightlessness require the development of appropriate animal models and instrumentation systems to document the process of adaptation. Newly developed blood pressure and flow instrumentation for use with the Rhesus monkeys has been developed at Ames. To date, 8 months of valid data have been obtained from instrumented animals.



Blood pressure and flow transducer

This instrumentation represents a significant advance in transducer design. Measurements can be taken from extremely small vessels (2-3 mm diam) without their invasion. Blood flow is detected using ultrasonic crystals, while blood pressure is detected by aplanation (20% constriction) of the vessel wall using an implantable strain-gauge cell with a 4.5 mm diam. Transducers of appropriate size (14 mm long) are placed on a carotid artery in the monkeys to document hemodynamic changes of cerebral circulation.

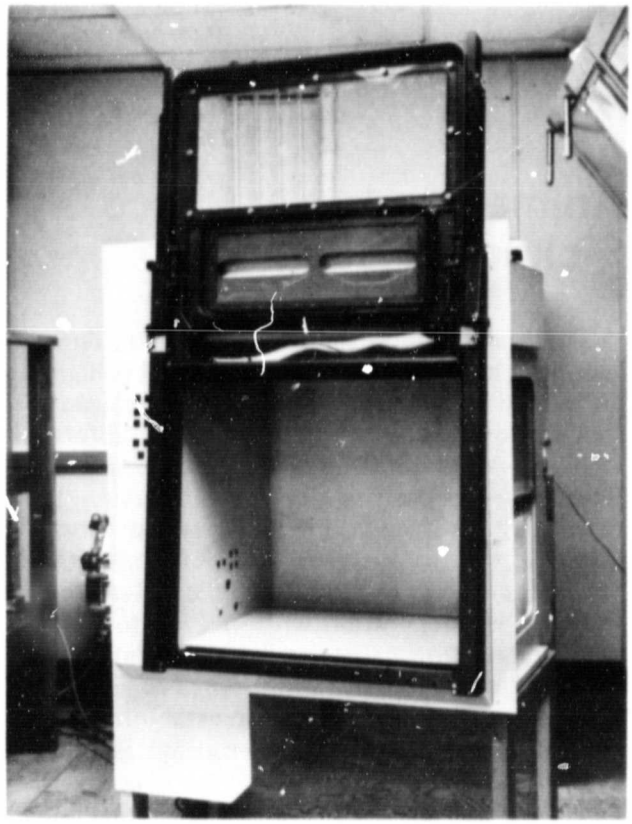
(H. Sandler, Ext. 5745)

Research Animal Holding Facility

Ames Research Center is the NASA lead Center for nonhuman life science experiments. The Life Sciences Flight Experiments Project Office is directing the development of flight-certified equipment needed to conduct many of the life-science experiments aboard Shuttle/Spacelab missions. One major piece of equipment that has been developed is the Research Animal Holding Facility (RAHF). It is designed to house either rodents or squirrel monkeys throughout Shuttle/Spacelab missions lasting as long as 30 days. Each RAHF has its own environmental control system to control temperature, humidity, airflow, CO_2, and O_2. Data were obtained on temperatures at various points in a RAHF, humidity, airflow rate, drinking water pressure, light monitor, and heater and cooler monitors, and on the food and water consumption and activity of each animal. Additional parameters can be measured given the installation of appropriate sensors such as biotelemetry implants. Photographic coverage of four rodent cage assemblies or one squirrel monkey cage can also be obtained. The first of four RAHFs to be built has been undergoing extensive testing to verify the design for spaceflight in the Spacelab. Functional, vibration, electromagnetic interference/electromagnetic compatibility, noise, thermal, etc., tests have been successfully conducted throughout the past months. A rodent biocompatibility test of the RAHF was run continuously for 14 consecutive days using a fully populated RAHF connected to the ground support equipment and data systems.

(G. Bowman, Ext. 6273)

General-purpose Work Station



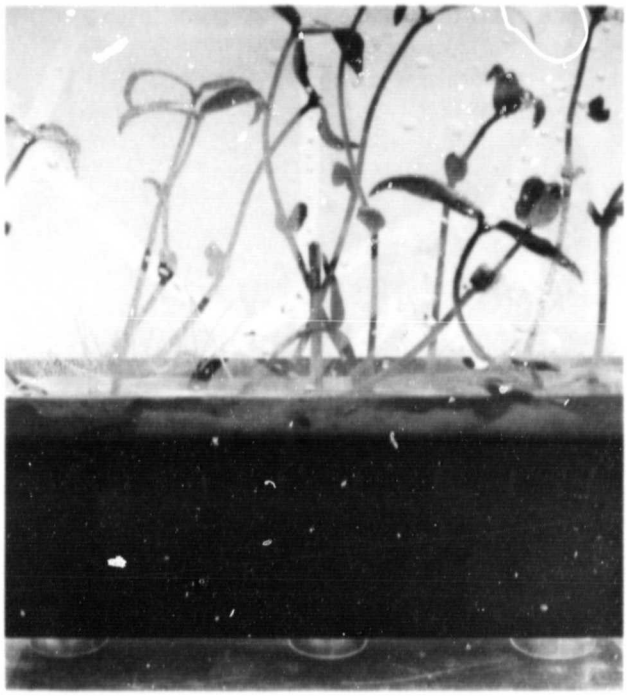
High-fidelity mockup of Spacelab General Purpose Work Station

The Life Sciences Flight Experiments project is developing the General-Purpose Work Station which will be used in the Spacelab pressurized module to support life-science experiments. A high-fidelity mockup is being constructed at Ames. The cabinet interior, when covered by the sliding door, provides recirculating air free from particles and volatile chemicals. Horizontal slits

provide astronaut-operator access with inrushing air that prevents spacecraft cabin contamination. The first flight for the equipment is scheduled for Spacelab 4.

(D. Buckendahl, Ext. 5767)

Plant Growth Unit



Plant growth unit

The Plant Growth Unit (PGU) was installed in the mid-deck of the Space Transportation 3 (STS-3) shortly before launch and performed as expected for the length of the flight. Mung bean, oat, and pine seedlings were grown in its six plant growth chambers. The PGU was removed from the Shuttle approximately 1 hr after landing at White Sands Missile Range, and the plants were recovered and examined. Chamber gases were analyzed for ethylene, and the plants were photographed and then preserved for further anatomical and chemical analyses.

Dr. Joe Cowles, the Principal Investigator (University of Houston), is conducting analyses of the plants to determine whether the lignin content and the enzymes leading to the production of lignin are decreased in weightlessness.

The successful operation of the PGU permits a variety of plant experiments to be included in Shuttle flights and thus the opportunity to advance the science of plant biology.

(E. Merek, Ext. 6745)

Waste Management for a CELSS Using Wet Oxidation

Waste processing will be an important subsystem within a controlled ecological life support system (CELSS) in space. The primary function of the waste-treatment system is to produce plant nutrients from human, plant, and possibly, animal wastes.

Wet oxidation is a waste treatment process which oxidizes a waste slurry at elevated pressures and temperatures. The liquid effluent from this process contains many of the trace minerals needed to grow healthy plants.

It was discovered that corrosion products from a wet oxidation reactor can seriously impair the germination of lettuce seedlings. This finding suggests that considerable care must be exercised in the design and construction of the waste-treatment system to minimize the introduction of phytotoxic elements into the waste product system.

(T. Wydeven, Ext. 5738)

High-pressure Space Suit for Shuttle Extravehicular Activity

The current Shuttle space suit, which is designed to operate at 4-psi internal pressure, requires a time-consuming protocol of prebreathing pure oxygen and/or lowering the atmospheric pressure in the Shuttle cabin before an astronaut can don the suit without risk of getting the bends. It is desirable, for personal safety and for the ability to perform extravehicular activity quickly

and effectively, to have an 8-psi suit which does not require prebreathing or changes in ambient cabin pressure before donning.

Ames Research Center and Johnson Space Center have begun a collaborative program to build an 8-psi demonstration space suit, to be completed in early 1983. The suit will be modular and will employ a number of different concepts for the various joints. After testing and evaluation, the optimum configuration will be chosen, and the new suit will be considered as a replacement for the current Shuttle suit.

Ames has been developing high-pressure suit technology for a number of years, and many of the Ames designs will be incorporated into the new suit. These concepts include a variety of joint configurations, sizing capability for fitting a range of astronauts, and low-cost, reproducible manufacturing techniques for producing both fabric and metal portions of the suit. Ames is currently transferring its expertise (design drawings and instruction in manufacturing processes) to contractors involved in building various modules of the demonstration suit (ILC Industries, Inc.; Hamilton Standard Division of United Technologies; Life Support Systems, Inc.; and Suitech).

(H. Vykukal, Ext. 5386)

Carbon Isotopic Measurements in Rocks From Midocean Ridges and Hotspots

An accurate understanding of the early evolution of life requires that we know how organisms have affected the processing of carbon compounds in the Earth's crust and biosphere. Carbon enters the surface environment via volcanic eruptions, principally those which occur along midocean ridges and in hotspots. Carbon is then exchanged between its reservoirs in the ocean, the atmosphere, and sedimentary rocks. This exchange is influenced in many ways by living organisms, and the history of these influences is recorded in the chemical and isotopic composition of carbon in ancient sedimentary rocks.

The interpretation of biologically mediated isotopic variations within sedimentary rocks requires that the isotopic composition of the "new" volcanic carbon be well known. Analyses of midoceanic basalts reveal that the isotopic composition of this volcanic carbon is very constant worldwide and that it is equal to the average carbon isotopic composition of sedimentary rocks. These observations imply that the carbon isotopic inventory of sedimentary rocks has been unchanged over geologic time. Consequently, the carbon isotopic variations observed in these rocks can be used to infer the evolution of biological processes during the course of Earth's history.

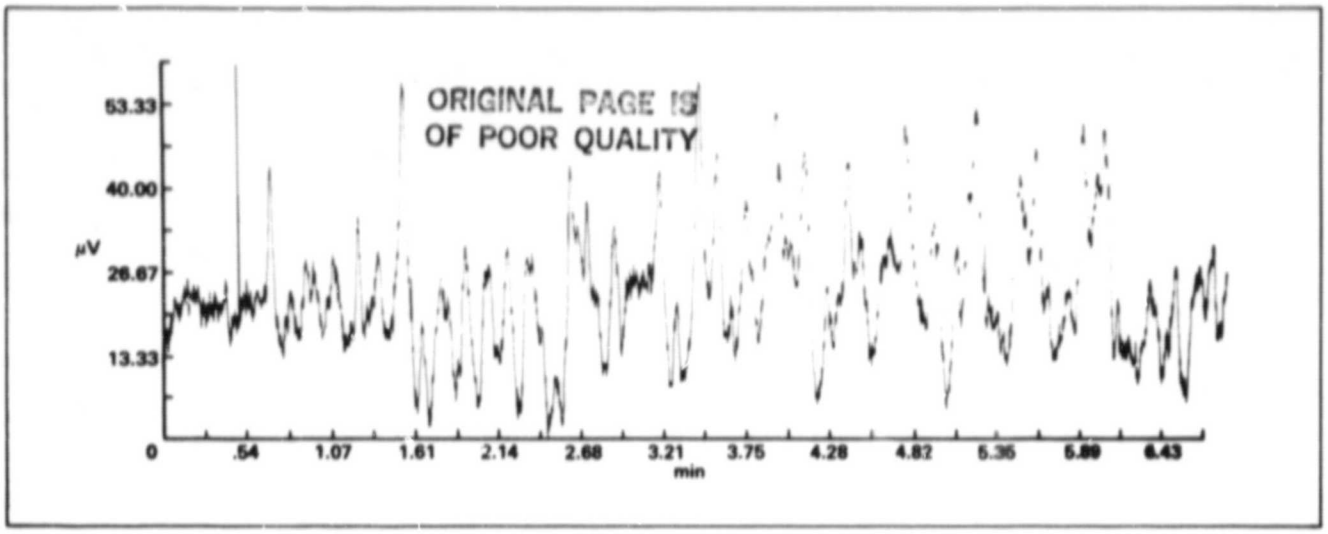
(D. Des Marais, Ext. 6110)

Muitiplex Gas Chromatography For Analysis of Volatiles

Gas chromatography has been widely applied to NASA's analytical needs, in the laboratory as well as in planetary atmospheres. As new applications are found, particularly in the analysis of volatiles, improvements must be made in sensitivity and speed. Recent studies of multiplex gas chromatography have provided a means to meet a significant part of the requirement.

Multiplex gas chromatography is a technique in which a number of consecutive samples are rapidly admitted to a gas chromatography column without regard to the elution or analysis time of the sample components. The components in each sample are then separated from each other, but appear in the column output as unresolved signals which cannot be identified with a specific sample, as shown in the raw data. The signal is then subjected to mathematical deconvolution using Fourier transforms. The primary benefits of this technique are the large, effective sample size and the dramatic increase in analyses per unit of time.

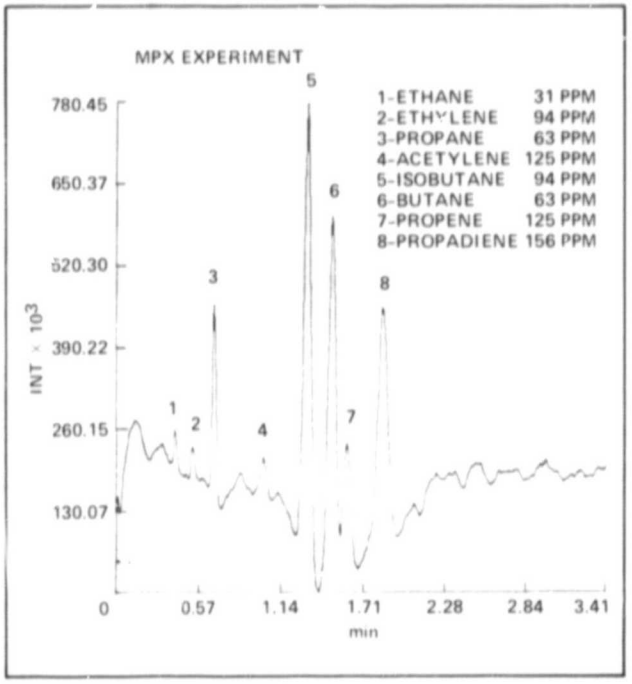
Multiplex chromatography has now been shown to be useful for analyzing complex mixtures of volatiles. Further, experiments using multiplex gas chromatography have demonstrated that effective sensitivity can be increased a



Raw data output from multiplex gas chromatography

hundred-fold. Using a standard laboratory gas chromatograph thermal conductivity detector with a sensitivity of 10 ppm for butane in the conventional mode, researchers achieved a sensitivity of 100 ppb for butane with the multiplex-gas-chromatography technique.

(G. Carle, Ext. 5765)



Deconvoluted data demonstrating the resolution of eight hydrocarbons, integrity of retention times, and quantitative aspects of peak height.

NASA Aviation Safety Reporting System

The Aviation Safety Reporting System (ASRS) is designed to act as a voluntary, nonpunitive, and confidential program to collect reports which may provide valuable safety information regarding factors that cause or contribute to the occurrence of human errors and other problems in the national airspace system. Safety-related data are extracted from ASRS reports provided by pilots, air traffic controllers, and other members of the aviation community; the data are used for immediate and long-range purposes. If the safety information is considered to be time-critical, it is used immediately to alert those persons and organizations who can do something about the specific problem or condition. All collected data are coded and entered into a computer data base for use in continued research efforts initiated by NASA investigators and members of the aviation community, including the Federal Aviation Administration (FAA) and the Department of Defense. By acting as a central point for the collection of aviation safety data, the ASRS program can also detect trends within the airspace system and advise the community of any developing problems.

The ASRS is funded jointly by NASA and the FAA, although the latter agency has no direct role in the program's management. The program management is vested in the Life Sciences Directorate at Ames. In addition to addressing issues

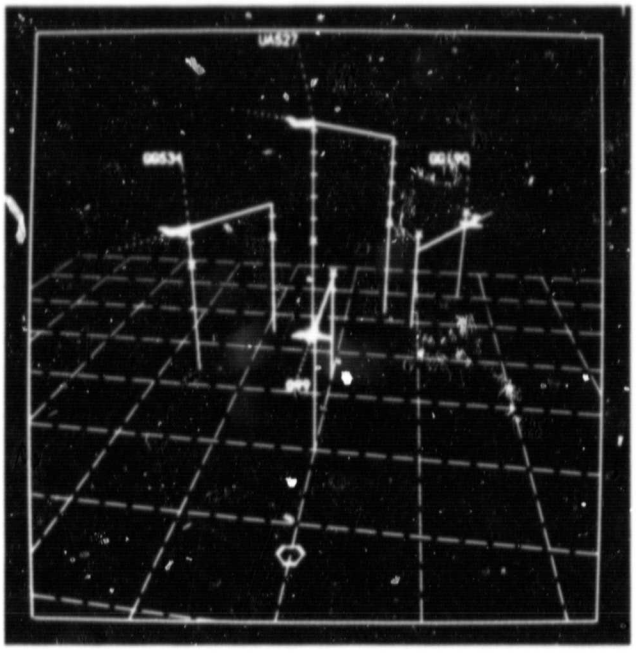
identified by reporters throughout the aviation community, the ASRS functions as part of NASA's ongoing research into human factors in the aviation environment. In that role, while the ASRS gathers current data, the Man-Vehicle Systems Research Office continues to perform analytical studies of human performance and behavior in the operational environment.

During the 77 months (April 1976 to September 1982) of the ASRS operations, 32,327 reports were received and processed, and 742 alert bulletins (time-critical information) were disseminated to the FAA, military aviation-safety organizations, and other members of the aviation community. In addition to the alert bulletins, safety information was disseminated by means of ASRS Quarterly Reports and special studies; as of the first of September 1982, 13 Quarterly Reports had been generated and 398 special data studies had been performed. The ASRS program has also published 39 issues of a monthly safety publication, CALLBACK, which is widely circulated to the aviation community and designed as a brief, easily readable means of sharing safety data considered important and timely by the ASRA staff.

(W. Reynard, Ext. 6467)

Cockpit Traffic Displays

Recent laboratory experiments have examined a variety of techniques for encoding vertical separation of conflicting aircraft on electronic, moving-map displays. One of the more interesting is a three-dimensional perspective display of air traffic made from an eye point above and behind a pilot's own aircraft. The addition of metric information in the form of a grid and 1000-ft-altitude tics on vertical "noselines" dropped from the aircraft has provided pilots with the necessary separation information for making avoidance maneuvers. Comparison of the patterns of pilots' avoidance maneuvers made using the perspective traffic display with those made using more conventional plan-view displays, has shown that the previously observed preponderance of purely horizontal avoidance maneuvers probably reflects biases due to the display format. With perceptive displays, pilots make considerably more composite maneuvers, combining turns with climbs or



Cockpit traffic displays

descents. Preliminary analysis indicates that pilots make maneuver decisions 10 to 20% faster using perspective displays than when using several plan-view formats to view identical sets of encounters. Additionally, the perspective display reduces the pilots' perception of collision threat posed by conflicting aircraft and thus reduces the number of avoidance maneuvers selected.

(S. Ellis and E. Palmer, Ext. 6147)

Flight Crew Communication

Recent airline tragedies have stimulated a substantial amount of interest in crew performance and coordination. Some of these accidents have been partially attributed to breakdowns in the communications process between flight crew members. The National Transportation Safety Board has observed that in certain instances subordinate crew members have been aware of potential problems, but have not communicated their concerns assertively enough to the pilot in command.

A recent study has shed new light on the role of communications in flight crew performance. The cockpit voice recordings of a full-mission

simulation were content-coded for all categories of communication between flight crew members. In this simulation, qualified Boeing 747 crews flew a trip from New York to London in which all aspects of the actual flight (visual and motion cues, air traffic control, and weather) were realistically duplicated. Moreover, the flight included mechanical malfunctions which increased pilot workload.

There were substantial performance differences among the crews, and the quality of crew performance and coordination was related to the way in which crew members communicated with each other. Crews who communicated less overall were not as proficient, but the style of communication was the most important variable. Crew efficiency was positively related to the number of observations about aspects of flight status, and proficient crews seemed to exhibit more cohesion. However, most significant was the finding that within the crews who performed best, there was a higher frequency of acknowledging the inputs of others. This behavior seemed to reinforce further communication and created an atmosphere in which information was freely exchanged.

The atmosphere on the flight deck has a strong effect on the communications process, and this atmosphere is largely a function of the captain's "management style." These findings are presently being incorporated into airline training programs with the hope that these insights will improve the crew coordination process.

(C. Foushee, Ext. 6114)

Reduced-visibility Simulation

Reduced-visibility conditions are associated with a disproportionate number of aircraft accidents and incidents. Simulation of reduced visibility is of particular importance, since in-flight research is generally not feasible under such conditions. Adequate simulation of reduced-visibility conditions requires a thorough understanding of (1) the optics of visibility reduction produced by fog, rain, etc.; and (2) the manner in which the human visual system responds to the resulting changes in scene characteristics. During the last year emphasis has been on continuing improvement in understanding what cues are important in impoverished visual conditions. A series of studies investigating judgment bias in the estimation of aimpoint during simulated final approaches was completed. These studies have demonstrated a bias toward judging the aimpoint too low, which apparently stems from the expansion of the visual field in the vicinity of the aimpoint, and is due to the asymmetry of the visual flow field. This finding is important since it potentially explains why pilots often undershoot the landing zone in reduced-visibility approach and landing accidents.

(D. Nagel, Ext. 5477)

Aeronautics

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OF POOR QUALITY

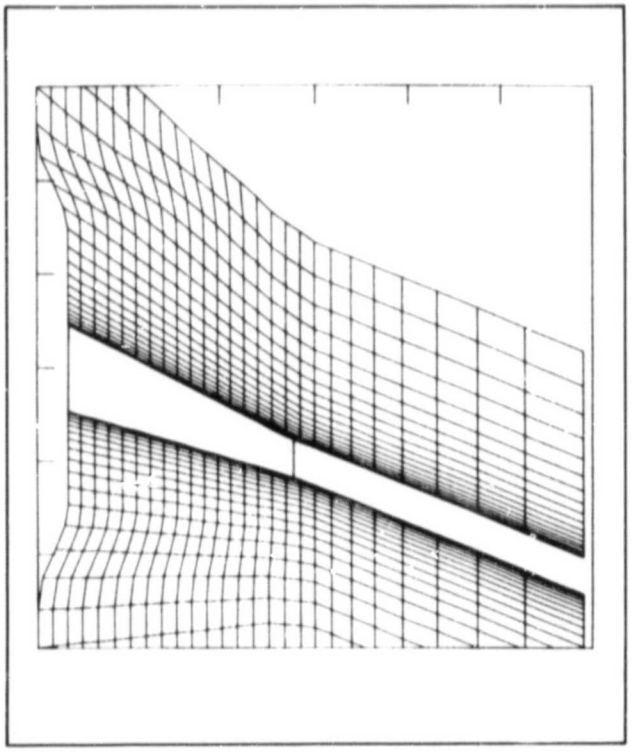
Computational Aerodynamics

The effect of bodies was incorporated in a recent modification of the highly efficient computer program, TWING. This new code solves the full potential equation using the implicit AF2 numerical algorithm to accurately describe the flow field and associated aerodynamic coefficients for various values of angle of attack and Mach numbers. Its use is especially worthwhile for the transonic flow regime. The vectorized version of the code is available on the CRAY 1S vector computer. The optimum 5-sec computational times, which can be achieved on this computer, make the code particularly economical to use in numerical optimization procedures for obtaining ideal aerodynamic surface shapes.

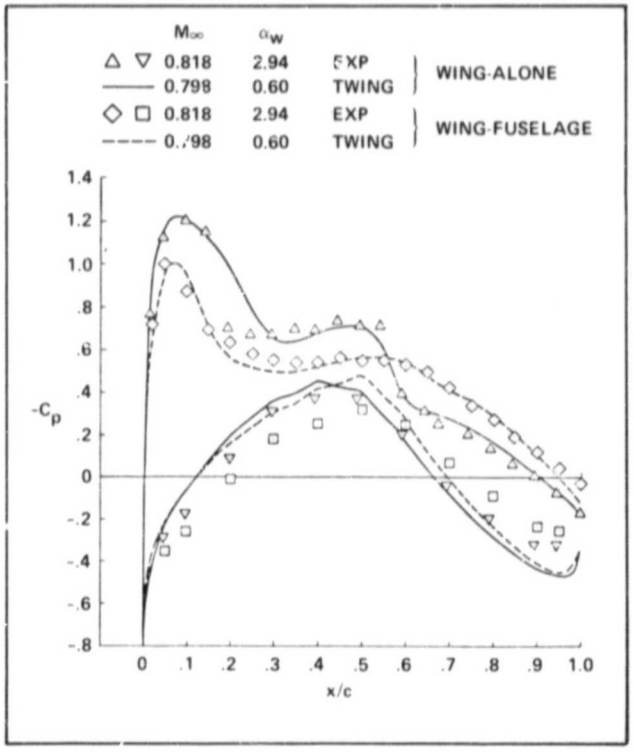
(P. Kutler, Ext. 6032)

Three-dimensional Grid Generation

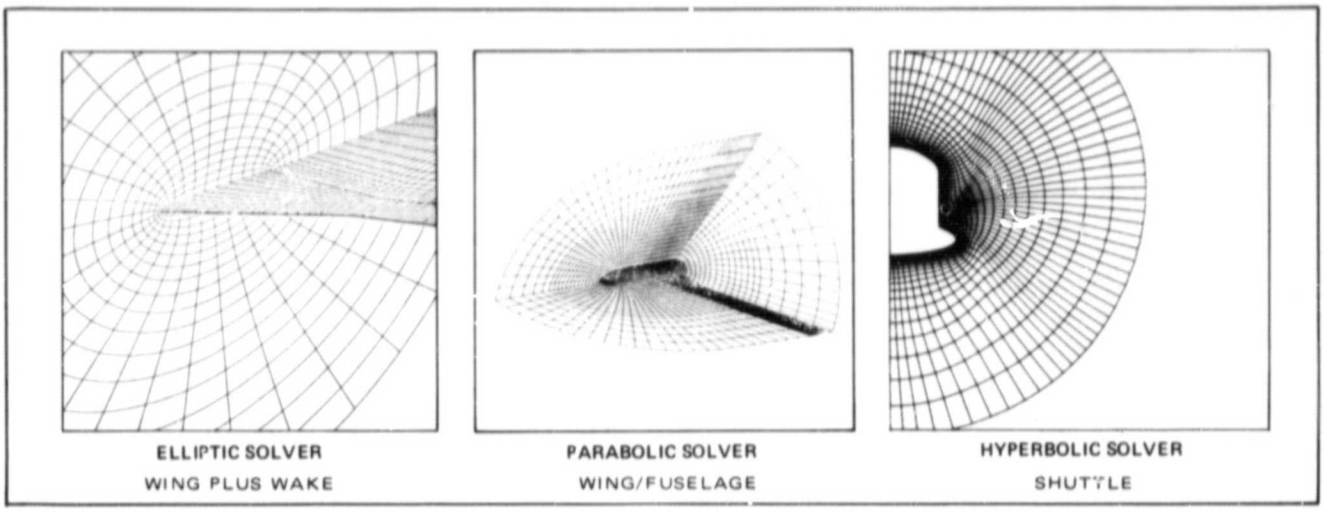
The discretization of the flow field around complicated aerodynamic configurations remains as one of the most challenging problems in the field of computational fluid dynamics. The discretization of the flow field influences the efficiency and accuracy of flow simulations. The ability to simulate the flow around complicated configurations is hampered by the difficulty of discretizing the flow field around such shapes. Elliptic, parabolic, and hyperbolic solvers are typical approaches being considered. The hyperbolic solver starts at the body surface and generates the grid by moving outward; however, there is no control over the shape of the outermost coordinate surface. Such a grid is, however, the least costly. The parabolic solver allows control of both the inner and outer boundaries and is only slightly more costly; it is a noniterative procedure. The elliptic procedure allows the



Numerically generated grid about a wing-fuselage configuration: planform view



Pressure coefficient comparison, isolated-wing and wing-fuselage results ($2y/b \cong 0.15$, root station)



Three-dimensional grid generation

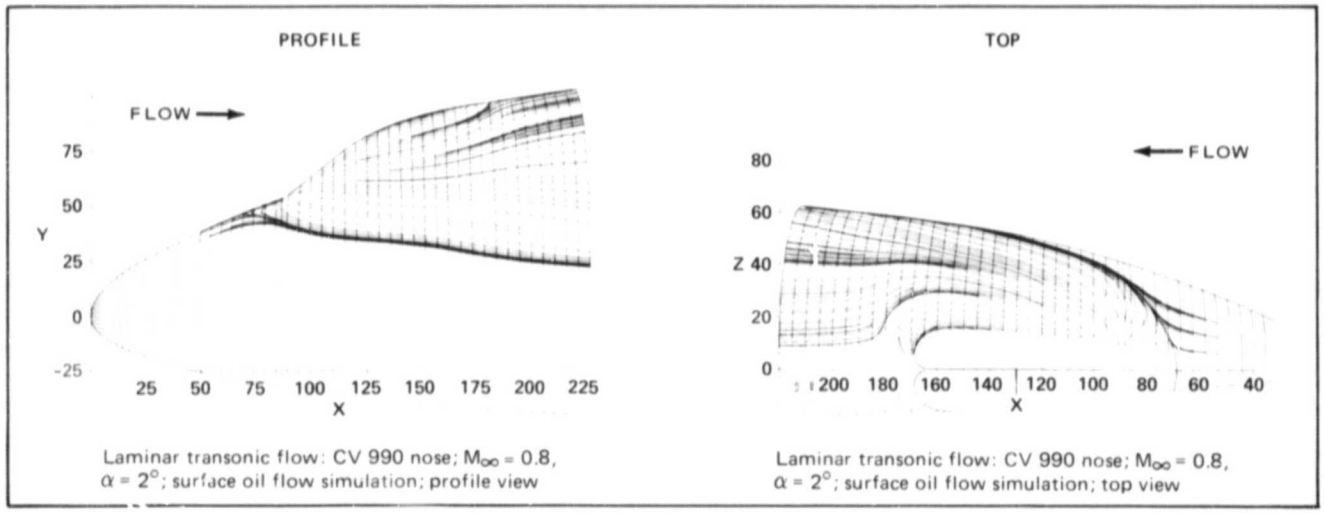
greatest control of the entire grid, but it is the most costly to obtain, because it is an iterative procedure.

(P. Kutler, Ext. 6032)

Convair 990 (Galileo II) Flow-field Simulations

Detailed knowledge of the transonic flow field surrounding the canopy region of the Convair (CV) 990 (Galileo II) fuselage is necessary for the design of a meteorological experiment. This experiment will accumulate accurate data relating to atmospheric gusts and other flow eddies along the flightpath of the CV 990. For the experiment to be effective, it is necessary to (1) measure the flow variables accurately and (2) place the sensors appropriately on the aircraft. It is in this manner that computational fluid dynamic methods are proving very effective in this application. Given the flight parameters, such as speed, angle of attack, and yaw, the flow field around the aircraft (including pressure and velocity) can be accurately computed. Typical of the results desired are the particle-path lines that permit the proper placement of the sensors.

(P. Kutler, Ext. 6032)

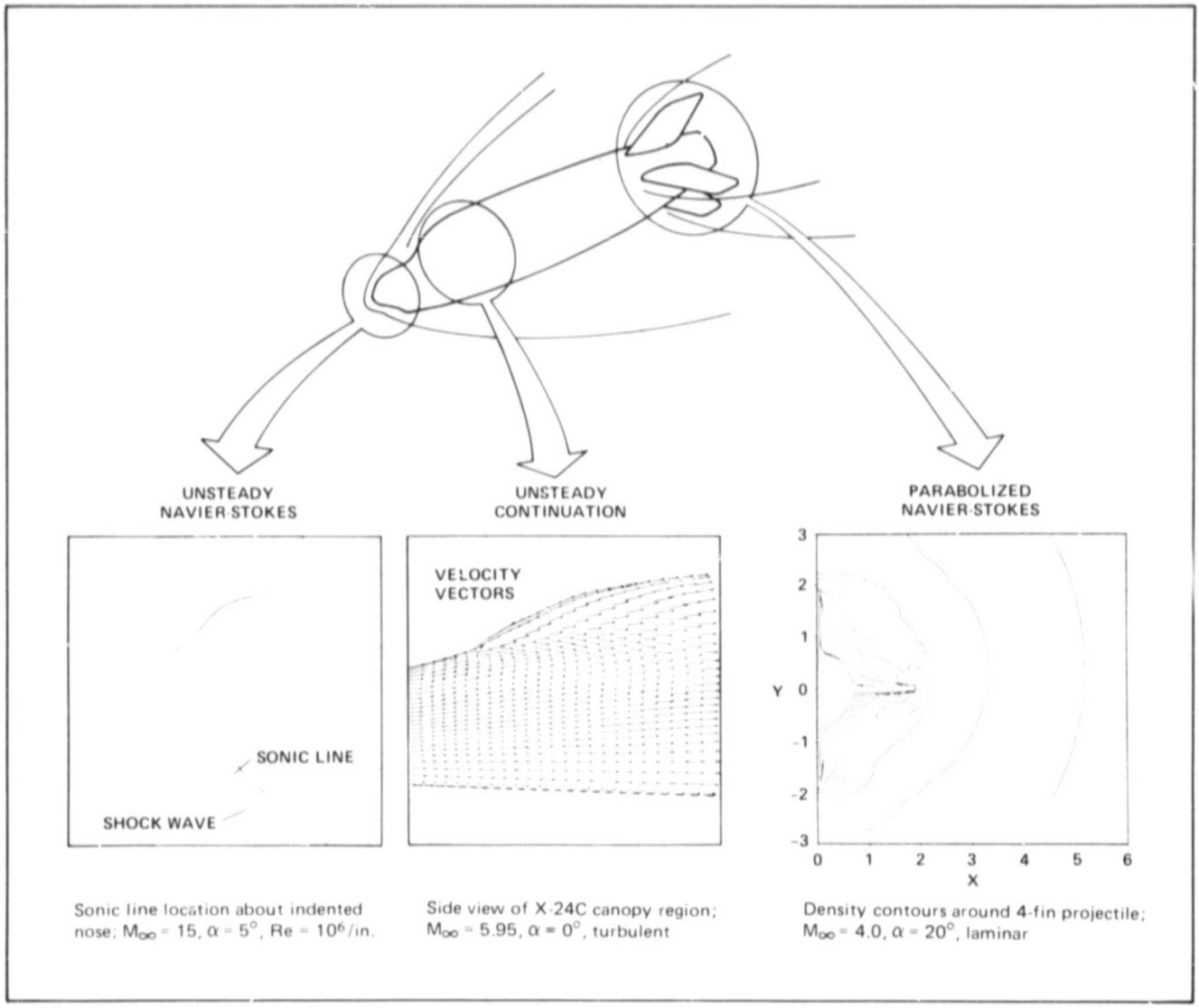


CV 990 (Galileo II) flow field simulations

Supersonic Viscous Flow Simulations

There now exists a complex of available computer codes that permits accurate simulation of the entire viscous flow field around a variety of practical supersonic/hypersonic configurations. This set includes the Unsteady Navier-Stokes, Unsteady Continuation, and Parabolized Navier-Stokes (PNS) codes. The Unsteady Navier-Stokes code is used to compute the flow in the stagnation (subsonic and transonic) region of the flow. These results are used as initial conditions for the PNS code. This latter code, however, fails when either streamwise flow separation or an embedded subsonic pocket of flow develops. The Unsteady Continuation code was developed for use in such regions. This entire complex of codes is being used to compute flows around a variety of practical configurations, including the X-24 maneuvering reentry vehicle and several current military projectiles and missiles.

(P. Kutler, Ext. 6032)



Sonic line location about indented nose; $M_\infty = 15$, $\alpha = 5°$, $Re = 10^6$/in.

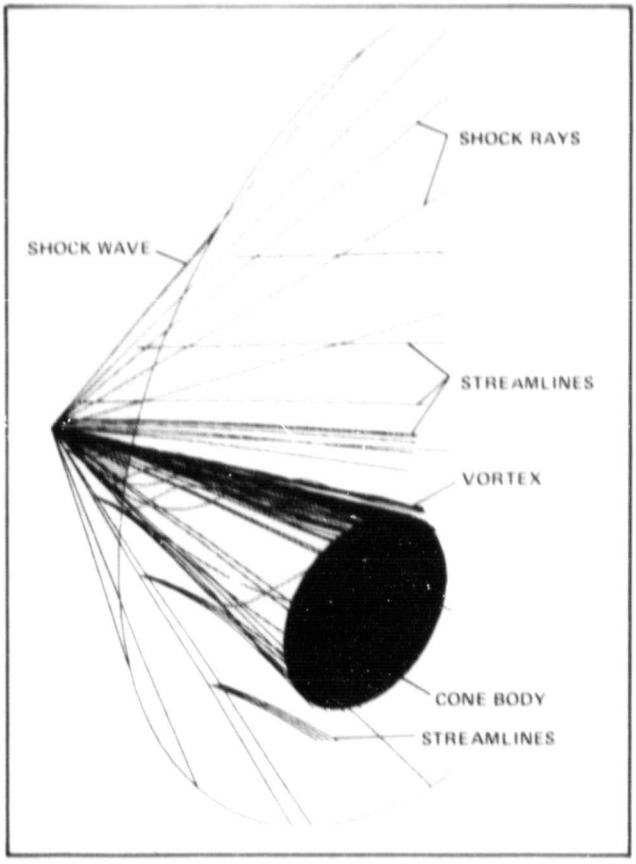
Side view of X-24C canopy region; $M_\infty = 5.95$, $\alpha = 0°$, turbulent

Density contours around 4-fin projectile; $M_\infty = 4.0$, $\alpha = 20°$, laminar

Code complex for supersonic viscous simulation

Calculation of Turbulent Flows

Numerical solutions of the Reynolds-averaged Navier-Stokes equations with various turbulence models were obtained for a variety of flows for the 1980-81 AFOSR-HTTM – Stanford Conference on the Prediction of Complex Turbulent Flows. The results of these calculations showed that many of the flow features observed experimentally were simulated by the computations.



Oblique view of the cone

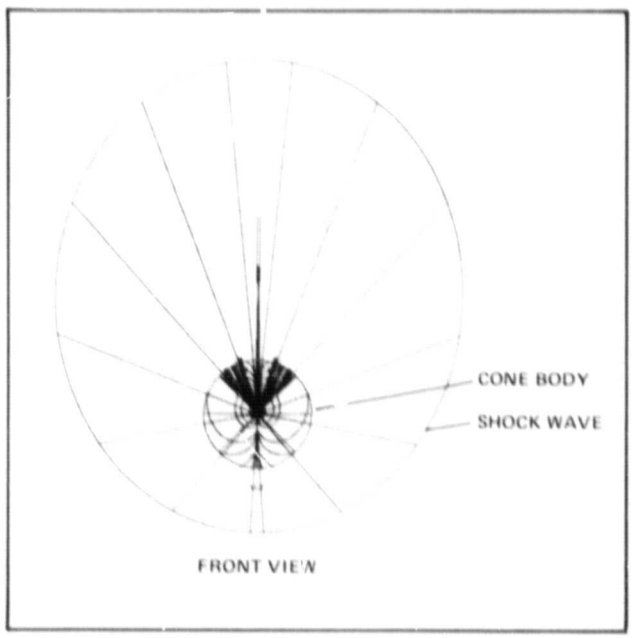
Turbulent supersonic flow around a pointed cone at large angle of attack has been calculated, and the large turbulent vortices in the flow field have been simulated using computer graphics. The simulation helps researchers to understand the structure of the three-dimensional viscous flows, leading to a better interpretation of surface flow patterns observed in wind-tunnel tests.

A Parabolic Navier-Stokes computer code was used to calculate the flow field over a 12.5° pointed cone at an angle of attack of 22.75°. The Mach number was 1.8 and the Reynolds number was 25 million. The use of the numerical solution for the velocity field permits the streamlines to be traced and displayed from various viewpoints in color on a computer screen.

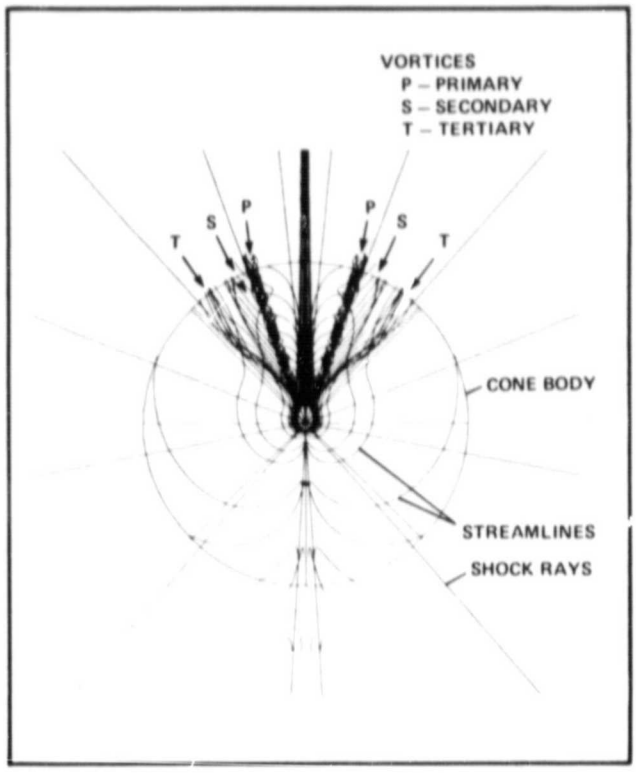
The oblique rear perspective of the cone shows the bow shock and a number of streamlines that start on the shock surface and move toward the cone body. The full-frame and zoomed head-on views illustrate the details of the flow field near the cone surface.

Three vortices are observed on each side of the vertical plane of symmetry. (The symmetry condition was enforced in the boundary conditions for the computation.) The primary and secondary vortices rotate in opposite directions and behave as expected. The tertiary vortex was not anticipated, as the surface pressure is qualitatively unchanged by it. This vortex has the same rotation as the primary vortex and, apparently, would grow and replace the primary vortex when it is shed.

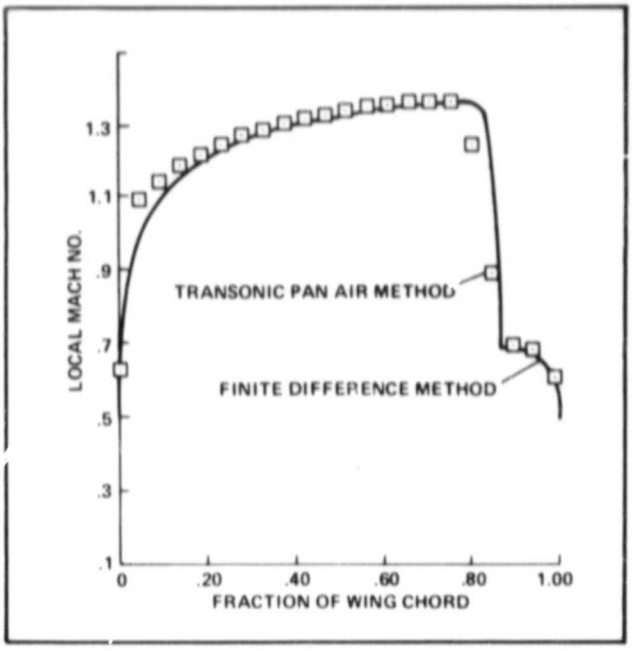
(J. Marvin, Ext. 5390)



Full frame head-on view



Zoomed head-on view



Potential flow at $M_\infty = 0.85$, NACA 0012 airfoil, $\alpha = 0°$.

Transonic Pan Air Development

PAN AIR predicts subsonic or supersonic flow around nearly arbitrary configurations. An extension to PAN AIR is being developed which will allow transonic flow to be predicted about the same configurations. This is done by solving the full potential equation or the Euler equations with an iterative procedure that combines PAN AIR source/doublet panels with a rectangular grid in physical space. Since the method does not use a body-fitted grid, the entire problem of generating such a grid and transforming it to a computational domain is eliminated.

The iteration procedure involves solving a set of linear Poisson equations. These equations are solved with fast Fourier transforms (FFTs), using the rectangular grid, and with PAN AIR panels which enforce the boundary conditions at the aircraft surface.

Compared with a finite-difference method, the transonic PAN AIR method has demonstrated good results for two-dimensional configurations. It is fast, requiring only 1 sec CPU (computer processing unit) time on a CRAY-1S. The speed is attributed to: (1) updated flow values given by the solutions to the Poisson equations at every point of the grid and at each iteration, (2) extremely efficient FFTs (on a CRAY-1S the FFT solution of the Poisson equation for two million grid points requires less than 2 sec of CPU time, and (3) calculations involving body-fitted grids are not needed.

(L. Erickson, Ext. 6216)

Separated Flows by the Vortex Method

The vortex method was developed to simulate turbulence in shear layers, separated flows, and wakes. Initial implementations were limited to simple geometries but demonstrated the feasibility of the method as an alternative to the usual Eulerian formulation of the equations of fluid motion. Modifications have been made to the method in two dimensions to treat arbitrary shapes, and solutions have been obtained for

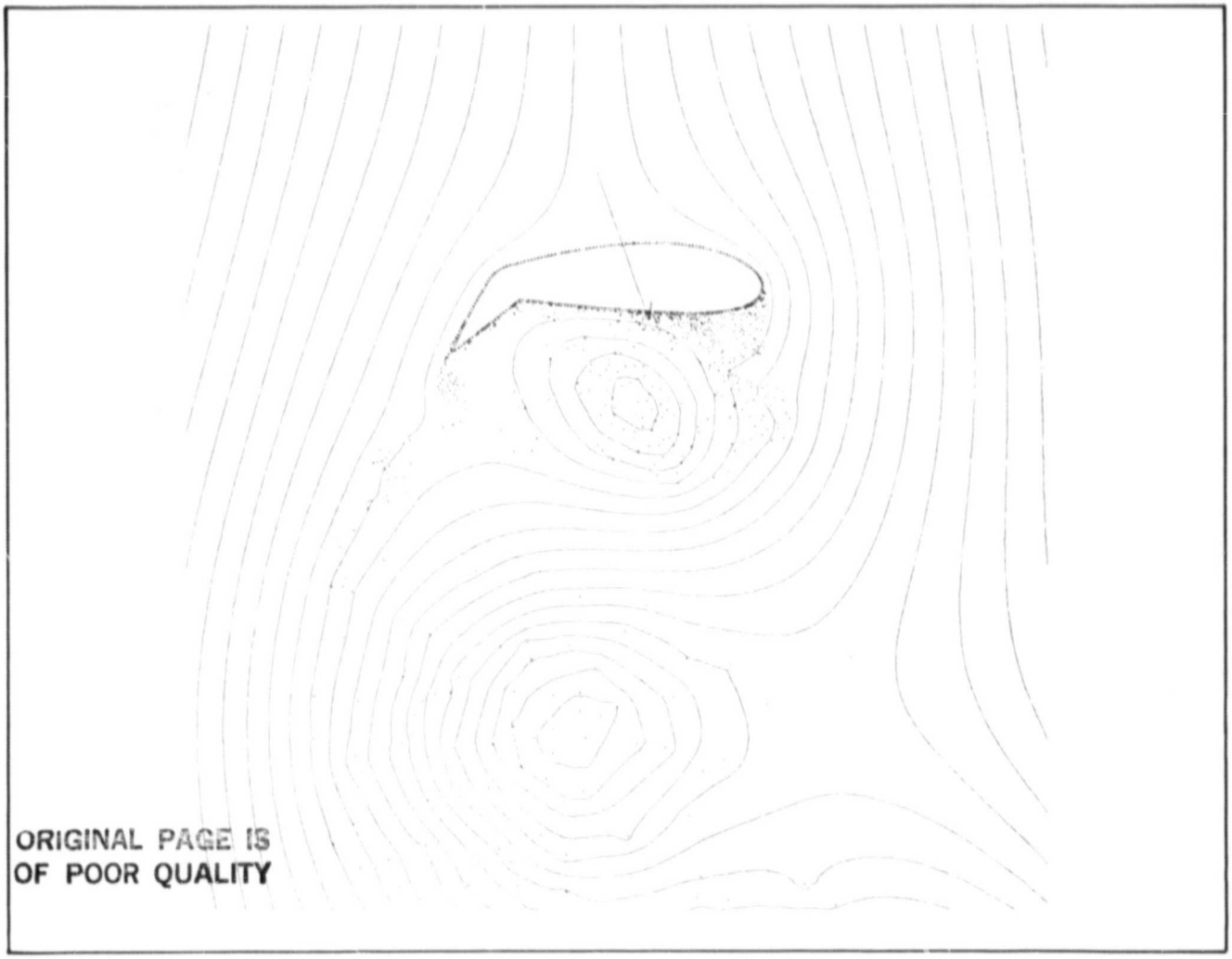
blunt bodies, stationary airfoils in steady and unsteady flow, and oscillating airfoils. Numerical results have been obtained for the flow around the wing of the XV-15 tilt-rotor research aircraft. In the hovering mode, the rotor wake impinges on the upper-wing surface and separates from the lower surface.

A vortex method in three dimensions has also been successful in solving turbulent flows, making it attractive for studying the vortex wake formed behind a large airplane and generated by the wing tips, flaps, and other protuberances. Further development of this method will make possible the use of computer simulations to devise means for locally altering the trailing vortices and thus reducing the hazard to other aircraft nearby.

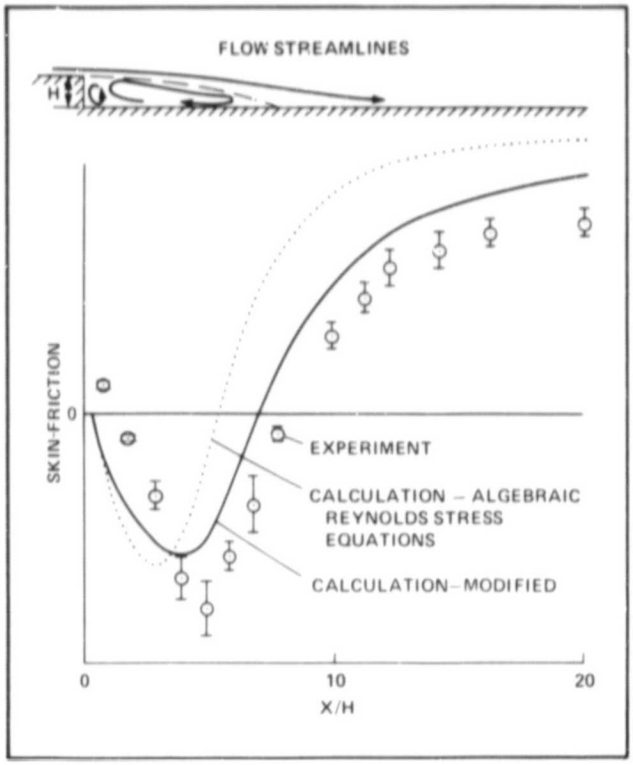
(A. Leonard, Ext. 6459)

Turbulence Measurements In a Separated Flow

Through detailed experiments, turbulence-modeling assumptions are being tested and improved, extending the applicability of computational techniques to strongly separated flow fields. One such experiment performed at Ames was a separated flow over a rearward-facing step. The data included surface pressures, skin-friction, mean velocities, Reynolds stresses, and triple-product correlations from which mixing lengths, eddy-viscosities, dissipation rates, and pressure rate-of-strain correlations were deduced. Computations done at the University of California,



Computer simulation of vortices and streamlines around the wing of the XV-15 tilt-rotor research aircraft in hover



Skin-friction distribution behind a rearward-facing step flow

Davis, showed that existing models were inadequate for predicting the flow. The UC Davis group, guided by experiments, made a modification to the Algebraic Reynolds Stress Equation model, resulting in a marked improvement in the computations.

(J. Marvin, Ext. 5390)

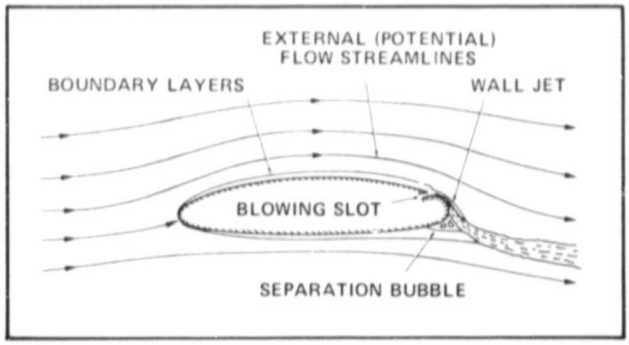
Airfoil Tests at High Reynolds Numbers

A second test leg for the High Reynolds Number Facility that incorporates a unique test section specifically designed and calibrated for two-dimensional testing, is fully operational. The new leg increased the test section size by a factor of 2.3 thus allowing transonic tests at Re = 1×10^6/ft to 30×10^6/ft. Experimental studies of the supercritical flow field around airfoils at angle of attack are under way with the goal of achieving test data of sufficient accuracy and utility for the validation of numerical methods. The test section employs side-wall boundary-layer removal to minimize side-wall interference effects, and adjustable upper and lower walls that are shaped to offset the adverse effects of mass removal and longitudinal boundary-layer growth and to follow the streamlines of the model in free air.

(J. Marvin, Ext. 5390)

Numerical Optimization of Circulation Control Airfoils

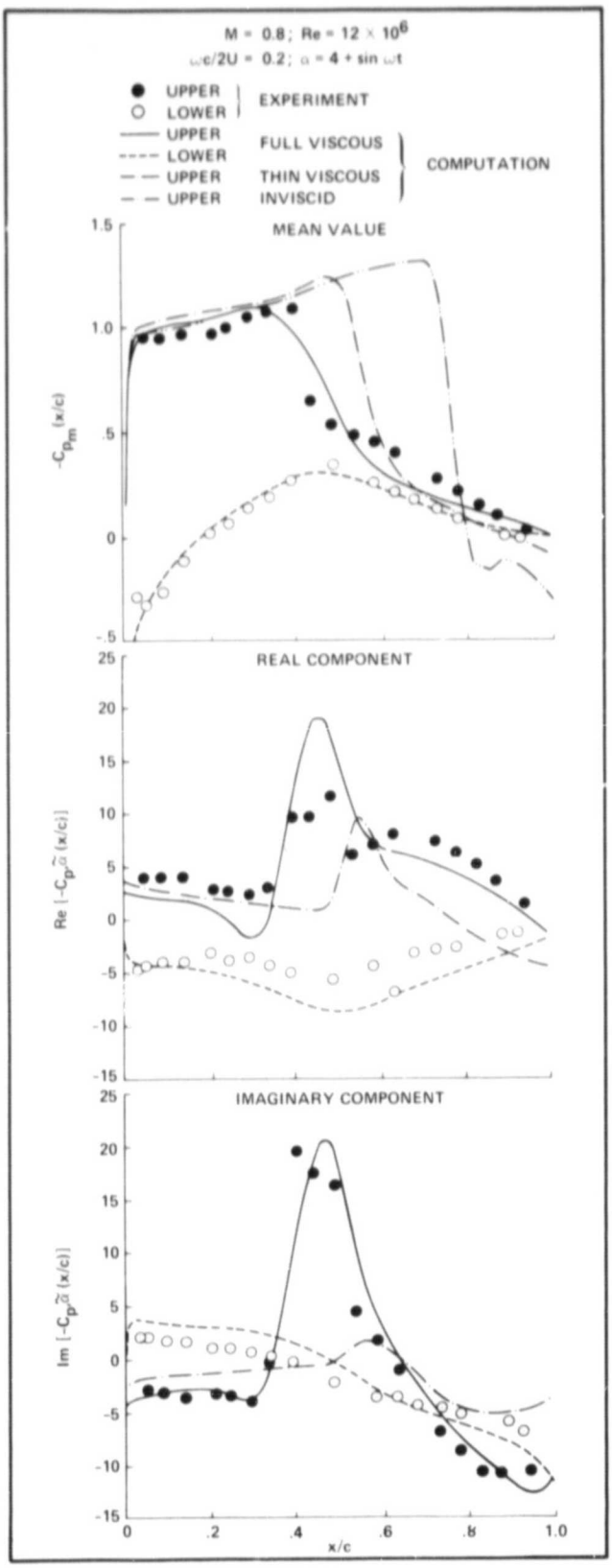
An advanced numerical procedure for optimizing the profile of circulation control (CC) airfoils has been completed. The computer program is being used by the Navy to improve the performance of its H-2/CC rotor-concept demonstration helicopter. After optimization of the airfoil profile, a wind-tunnel program will verify the improvement over the current design.



Circulation control airfoil

The design procedure consists of an optimization code, a viscous potential flow analysis for CC airfoils in subsonic or transonic flow, and an airfoil definition algorithm expressing airfoils as a linear combination of a set of basic airfoil shapes. The resulting computer program permits accurate optimization, subject to design variables, constraints, and objectives specified by the user, in a relatively short time. For example, on a CDC 7600, an optimization to maximize lift using three basic shapes and subject to several constraints required about 200 sec.

(G. Kidwell, Ext. 5886)



Mean value and complex representation of surface-pressure (first mode)

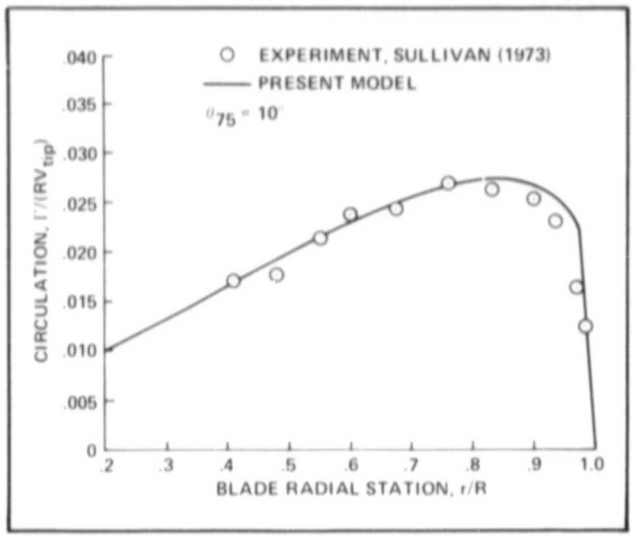
Unsteady Transonic Aerodynamics

The understanding of unsteady transonic flows about airfoils is important in treating such dynamic phenomena as flutter and buffet, and in the analysis of rotary-wing aircraft. Theoretical analysis of the flow is complicated by the presence of an unsteady mixed subsonic-supersonic region within the flow field. In addition, the unsteady shock-wave/boundary-layer interactions and the subsequent flow separation must be properly modeled. Efficient numerical techniques were developed based on the Navier-Stokes equations in a conservative form. Typical calculations were made for transonic flow over an oscillating NACA 64A010 airfoil where the shock wave separates the boundary layer over a portion of the cycle. The inviscid computation required 1.56 min/cycle of oscillation which is more than 80 times faster than earlier methods. The Navier-Stokes solutions required 8.64 min/cycle, but these solutions were the first of their kind for an oscillating airfoil with shock-induced separation. The mean value of the unsteady pressure, and the in-phase (real part) and the out-of-phase (imaginary part) components of the pressure with respect to the angle-of-attack variation were computed; the full viscous solutions compared well with experimental data.

(W. Chyu, Ext. 6116)

Unsteady Rotor Aerodynamics Using a Vortex-Panel Method

A computer program has been developed which calculates the potential, incompressible, three-dimensional flow about a helicopter rotor blade using an unsteady vortex-panel method. The mutual interaction between the blade and the distorting free wake is taken into account. The program can also predict the geometry of the time-dependent, three-dimensional wake and the instantaneous loadings for a single blade in hover, climb, and forward flight. The solution is obtained by using a time-accurate, step-by-step



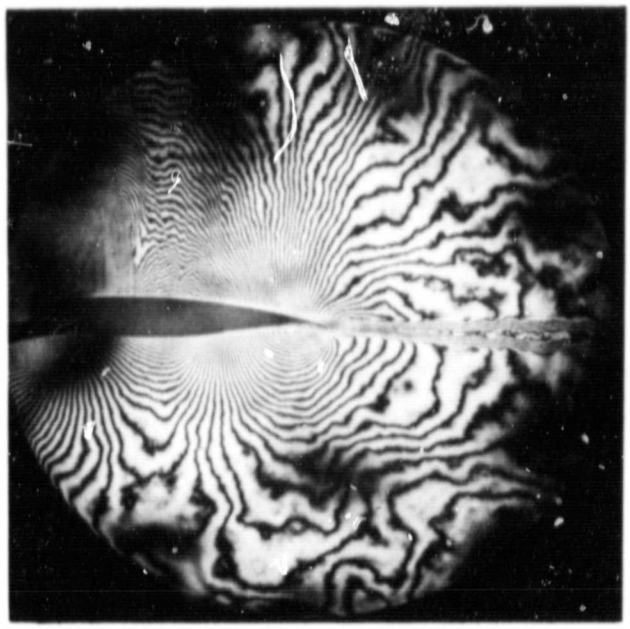
Radial variation of circulation for a single blade in hover — comparison between theory and experiment

procedure. The complex wake geometry at any time can be plotted using a computer graphics system. Calculated results are compared with published data for a rotor blade in hover and forward flight. The code has also been applied to study the effect of changing blade-tip geometry. The present method alleviates the need to rely upon measured-wake geometrics or prescribed-wake models to calculate the airloads.

(M. Tauber, Ext. 5656)

Supercritical Airfoil Boundary-layer and Near-wake Study

A unique set of boundary-layer and near-wake data has been obtained on an advanced supercritical airfoil section at near-design test conditions in the Ames 2- by 2-Foot Transonic Wind Tunnel. Advanced laser measurement techniques were combined with more conventional pressure-probe techniques to quantify the mean flow and turbulence fluctuations of the upper-surface boundary layer and near wake. The turbulence intensity and Reynolds shear-stress results (using the laser velocimeter technique) are the first such data to be obtained for a supercritical section at transonic test conditions. Another unique feature of the results is that redundant measurements of the



Holographic interferogram of the flow at the near-design test condition. In the regions outside the boundary layer and wake, the fringes can be interpreted as Mach number contours

mean-velocity profiles were obtained using pitot-pressure-probe and laser-velocimeter techniques. These redundant measurements provide a degree of confidence in the mean-velocity measurements that was lacking in previous studies in which only pressure probes were used. The Mach number distribution outside the boundary layer and wake was determined by holographic interferometry techniques.

The pronounced aft camber and flat upper surface of supercritical airfoil sections combine to make the performance of these airfoils dependent on viscous effects. Even at the design Mach number and lift coefficient, the thickening of the upper-surface boundary layer near the trailing edge caused by the aft camber is sufficient to have a first-order effect on the surface-pressure distribution. A significant change in shock location can also occur because of the flat upper surface which puts little constraint on the shock. Thus, any feasible predictive method must accurately account for the boundary-layer growth. However, because of the strong adverse pressure gradients at the shock and near the trailing edge, the correct modeling of the boundary-layer growth is not trivial. In addition to these boundary-layer effects, the performance of supercritical sections is sensitive to the flow character in the near wake.

Past comparisons of theoretical calculations and experiment indicate that further developments in theoretical modeling will be needed before accurate predictions of performance become a reality. The present experimental results will serve as a guide in the development of these improved theoretical models.

(D. Johnson, Ext. 5655)

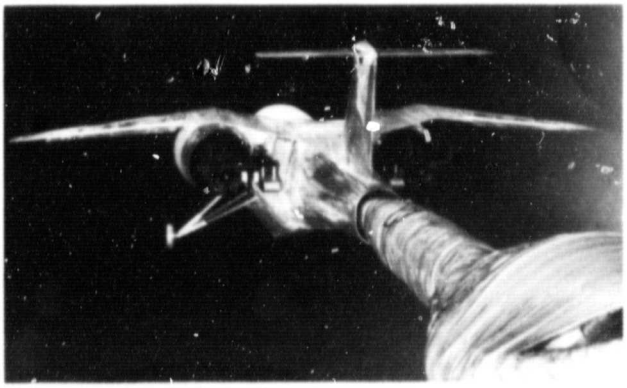
Wind-tunnel Test of an 11.4% Scale Model of a Tilt-nacelle V/STOL Configuration

In a cooperative program between NASA, the Navy, and Grumman Aerospace Corporation, a model of a tilt-nacelle V/STOL concept was tested in the Ames 12-Foot Pressure Wind Tunnel. This model is an 11.4% scaled version of the full-scale configuration previously tested in the 40- by 80-Foot Wind Tunnel. The model is powered by two high-pressure, air-driven engine simulators manufactured by Technology Development Incorporated. These simulators are scaled-down replicas of TF34 engines as used in the full-scale tilt-nacelle model. The model was tested over a Mach number range from 0.17 to 0.70 and a Reynolds number range from 1.2 to 7.0 million per foot. The angle of attack was varied from -2° to +2°, and the engine simulator rpm was varied to obtain power effects.

Force data were obtained using three internal balances. The first balance measured forces and moments on the nacelles, the second measured forces and moments on the airframe alone, and the third measured forces and moments on the entire vehicle. Approximately 450 pressures were measured on the model. Of these, 78 were used on one wing and the remainder were used to evaluate engine mass flow. In the final phase of the test, the engine simulators were removed and flow through nacelles was used in an investigation of configuration component drags.

The test program provides aerodynamic data on a V/STOL configuration of particular interest to the Navy and provides an exceptional opportunity to compare small-scale and large-scale data on an identically shaped V/STOL aircraft with operating inlet and exhaust flows.

(D. Faulkner, Ext. 5645)

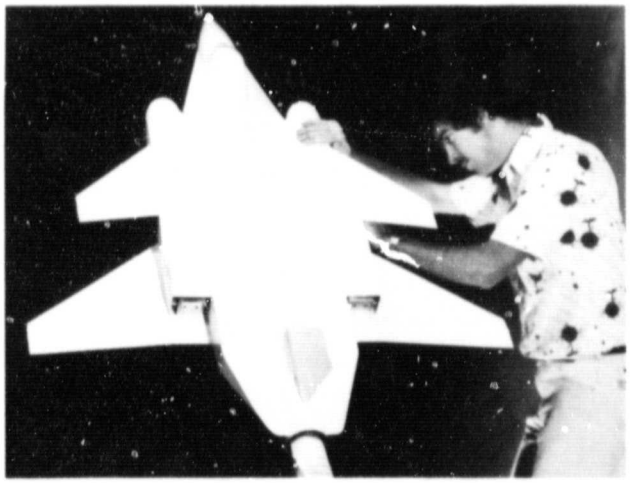


Tilt-nacelle V/STOL model in the Ames 12-Foot Pressure Tunnel

Twin-engine V/STOL Fighter Aircraft

A joint research program with NASA, the Navy, and industry to develop aerodynamic technology for future twin-engine V/STOL fighter aircraft is nearly complete. In Phase I of the two-phase program, four contractors completed conceptual designs and aerodynamic analyses. In Phase II, two contractors fabricated four wind-tunnel models to investigate aerodynamic uncertainties identified in Phase I. Ongoing wind-tunnel tests of these models this year included tests in the Ames 12-Foot Pressure Wind Tunnel, where angles of attack ranged from 0° to 90° at Mach 0.2 and from 0° to 40° at Mach 0.4. These tests emphasized high-attitude controllability and pitch-down capability.

(D. Durston, Ext. 5855)



General Dynamics twin-engine V/STOL model on high angle of attack support system in 12-Foot Pressure Wind Tunnel

Single-engine V/STOL Fighter Aircraft

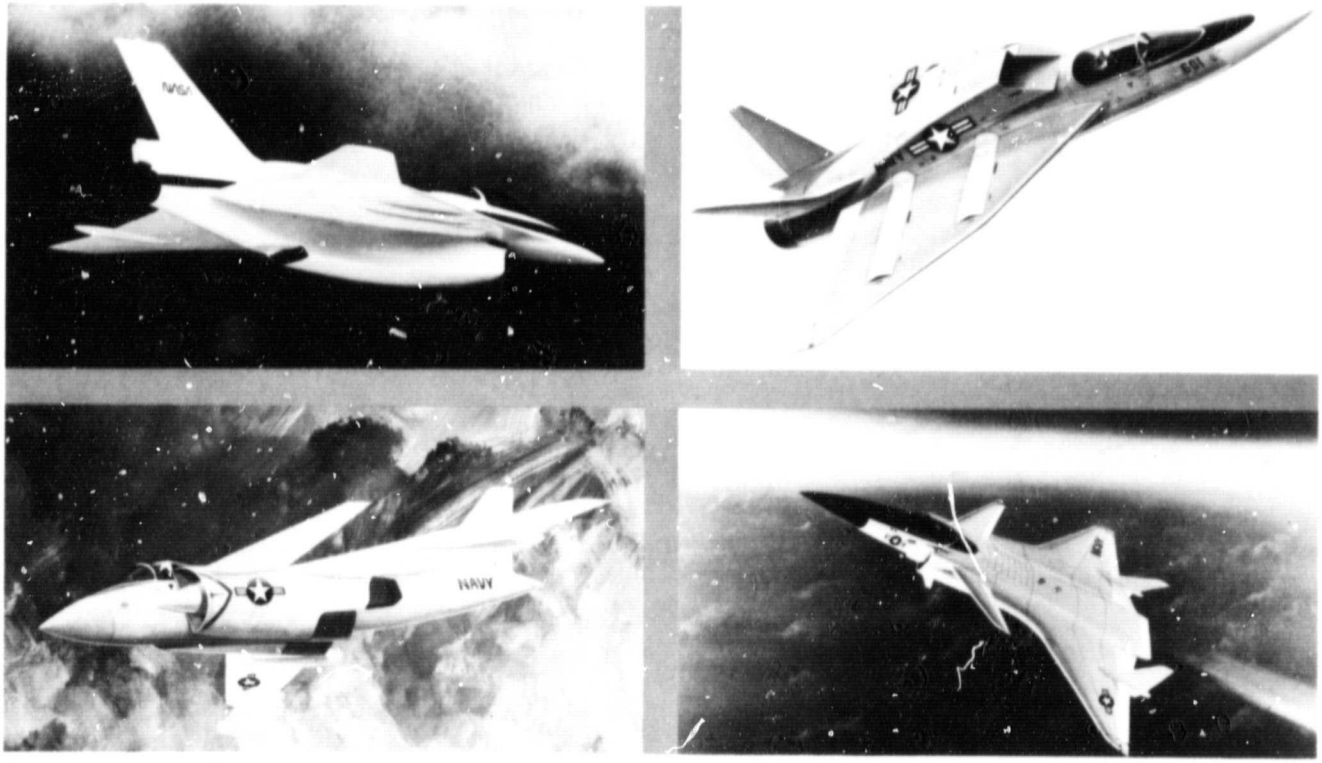
Aerodynamic technology for single-cruise-engine V/STOL fighter aircraft is under study in a joint NASA, Navy, and industry program. Four contractors completed Phase I of this program in early 1982. The objectives of Phase I were to (1) define promising single-engine V/STOL fighter concepts, (2) apply and assess aerodynamic prediction methods, (3) identify aerodynamic uncertainties associated with these concepts, and (4) propose a wind-tunnel program to investigate these uncertainties. Contractor concepts are shown. Two of the proposed concepts are wing-canard designs and two are tailless configurations. Four different propulsive-lift systems are featured. The General Dynamics concept uses a combination of ejectors and a deflected nozzle, the Rockwell concept uses ejectors only, the McDonnell Douglas concept uses four swiveling nozzles, and the Vought concept uses a tandem fan system.

Phase II, now under way, includes the design, fabrication, and testing of the General Dynamics and McDonnell Douglas concepts in the Ames Unitary and 12-Foot Pressure Tunnels.

(D. Durston, Ext. 5855)

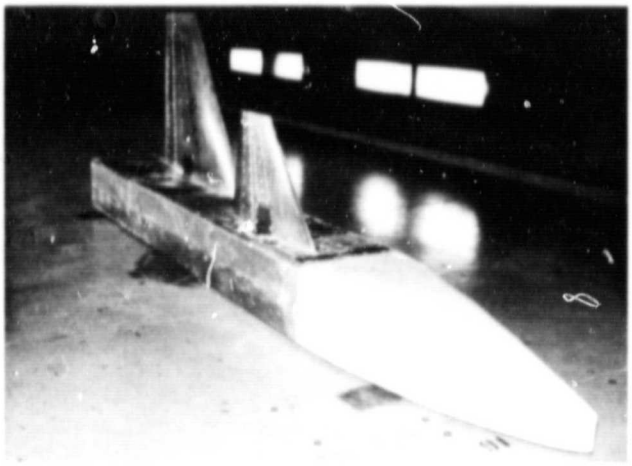
Propulsive Wing Aerodynamics

Various propulsive-flow techniques combined with a lifting surface have shown lift enhancement and drag reduction at both low and high speeds. To study multiple lifting surfaces with blowing, a wing-body-canard configuration with je blowing over the trailing-edge flaps of the wing an the canard was tested in the Ames 14-Foot Transonic Wind Tunnel at M = 0.6 to 0.9. The program was jointly sponsored by Ames, Wright Aeronautical Laboratories, the Naval Air Systems Command David Taylor Naval Ship Research and Development Center, and Rockwell-Columbus. The model was a semispan configuration with a wing that could be located in a high or low position and a variable-incidence canard that could be located high or low, forward or aft. Wing and canard jet blowing were independently variable over the full span or the half span. The wing and canard had replaceable leading edges for increased camber and trailing-edge flaps that could be deflected to 15°. Aerodynamic forces were measured using a five-component balance. Pressures were measured at approximately 200 orifices distributed on the wing and canard. The flow field downstream from



Single engine V/STOL fighter/attack aircraft

the canard was surveyed using seven-hole cone probes (wing removed). These probes, which can measure local flow angles up to 70°, were developed in a joint Ames/Air Force Academy program.



Propulsive wing model in 14-foot Transonic Wind Tunnel

Results generally showed that jet blowing increased lift at a constant angle of attack and lift/drag ratio at high lift coefficient. Simultaneous wing/canard blowing was slightly better than either wing or canard blowing alone. These favorable effects increased as jet blowing mass flow increased. However, jet blowing caused an increase in minimum drag, most pronounced at M = 0.9. This drag was thought to be caused by shock waves on the wing and canard flaps generated by expansion of the jet plume through the convergent nozzle. A possible solution to this problem might be a convergent/divergent nozzle which could cause some or all expansion to occur internally.

(D. Smeltzer, Ext. 5855)

Experimental Investigation of a Jet Inclined to a Subsonic Crossflow

Experimental investigations have been conducted to (1) determine the surface-pressure distribution on a flat plate and a body of revolution with a jet issuing at a large angle to the free stream and (2) obtain a better understanding of the flow field close to the jet exit by quantitative mean-velocity surveys. These experiments are designed to simulate the flow beneath vertical take-off and landing vehicles whose lift is obtained from downward-directed jets. These data will be used to develop mathematical models that will predict the pressure distribution and flow field around these vehicles.

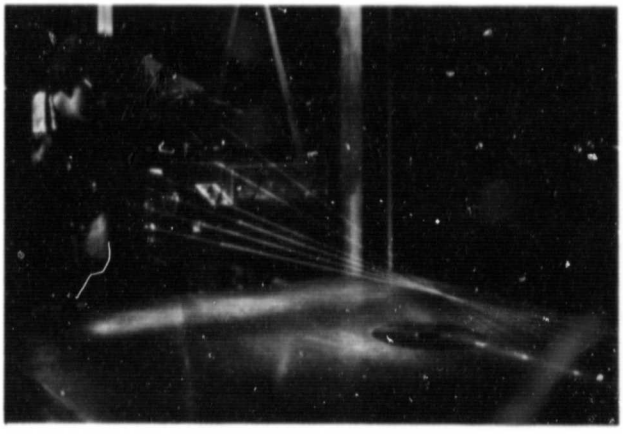
Pressure data were obtained with two flat-plate models at several nozzle injection angles. The first model had a single round nozzle whereas the second one had two round nozzles spaced two to six nozzle diameters apart. For the body-of-revolution model, data were obtained at several nozzle injection angles with a single round jet and with two round jets spaced two to six nozzle diameters apart. Mean velocity measurements were obtained with laser velocimeter surveys near the base of a round jet exhausting normal to a flat plate.

For the flat-plate model with a single jet, the suction pressure field shifts downstream and the jet entrainment effect decreases with decreasing nozzle injection angle. For the body-of-revolution model with dual jets exhausting perpendicular to the crossflow, the jet-induced effect of the rear jet on the surface-pressure distribution was less than that of the front jet. The pressure data of the flat-plate model with dual jets and the body-of-revolution model other than the 90° nozzle angle are being analyzed.

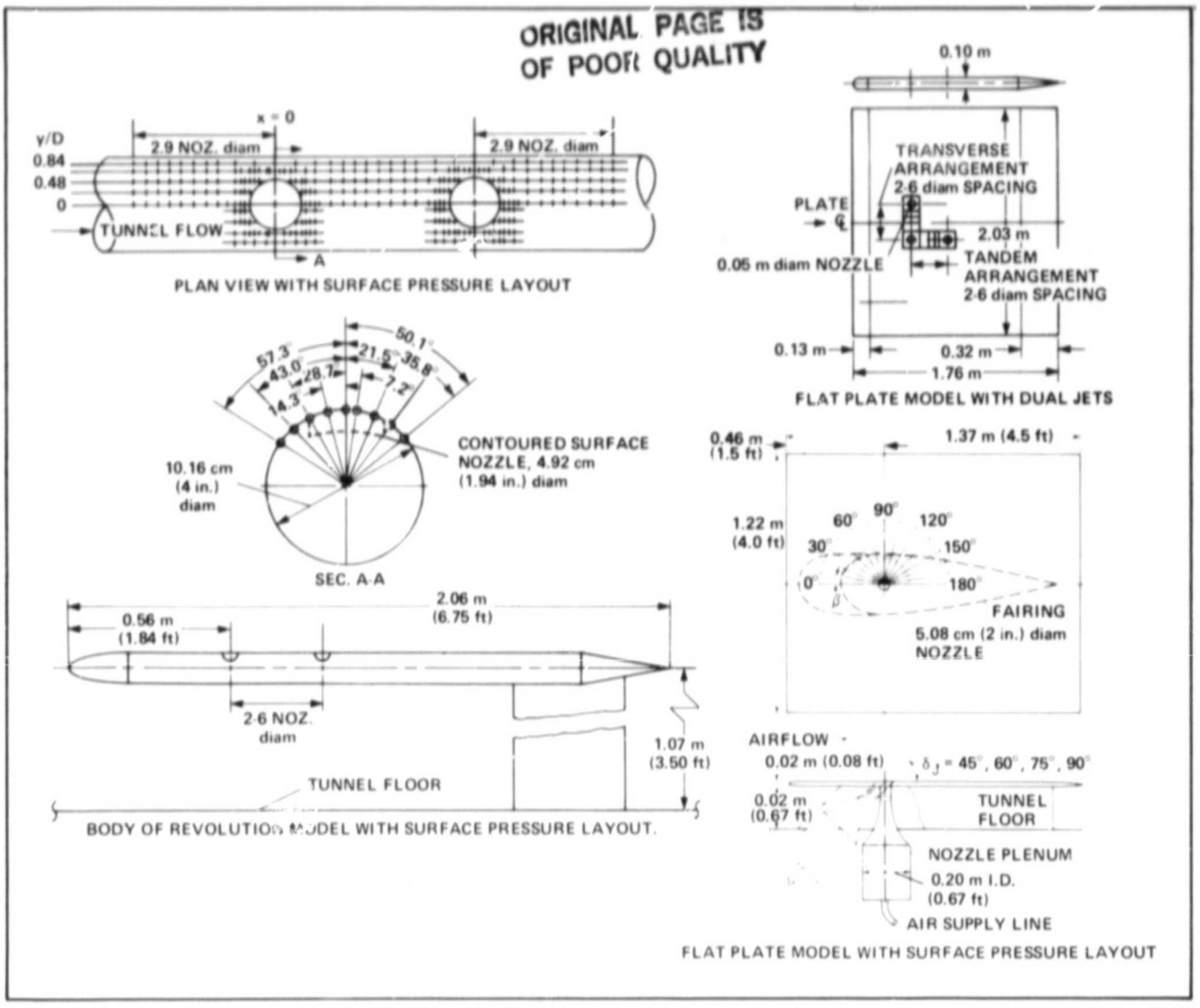
The laser surveys defined the upstream flow region, the accelerated swirl flow region around the jet, and the wake region behind the jet. Further laser surveys are planned to define the entrainment mechanism around the jet using the flat plate models and the body-of-revolution model.

The significance of these studies is that a nonintrusive flow measurement technique with a laser was used to obtain flow-field details impossible to obtain using other methods.

(K. Aoyagi and P. Snyder, Ext. 5047/6680)



Nonintrusive laser flow measurement technique



Single jet flat-plate model with surface-pressure layout

Propeller Acoustics

An experimental study was performed in the Ames 25- by 18- by 11-Foot Anechoic Chamber to determine the effect of perturbing the flow field forward of the propeller. The perturbation was caused by a circular jet of air, whose diameter was approximately one blade chord. The jet was directed at the propeller at various angles in two planes, horizontal (blowing chordwise from the leading to the trailing edge of the blade) and vertical (blowing spanwise from blade tip to hub). The changes that the variation of the direction of the jet caused were studied at various propeller speeds, blade loadings, and jet characteristics such as speed and turbulence. A method is being developed to predict the levels of the harmonics produced in the various cases.

Basic research such as this will advance the understanding of propeller noise generation mechanisms which can then be applied to such complex problems as the effect of mounting a tail or a wing forward of a propeller on an aircraft. Since the effects of propeller installation detail are significant contributors to propeller noise, this research is expected to make propeller-driven aircraft more acceptable to the community.

(G. Jonkouski, Ext. 6676)

Propeller noise in a perturbed flow; peaks of the harmonics at 3300 rpm, 0% thrust

Improved Airframe/Propulsion Integration Testing Technique

A promising wind-tunnel test tool for simulating complete propulsion-system-induced effects on highly integrated aircraft configurations is being developed at Ames in cooperation with the Air Force Flight Dynamics Laboratory. This technique involves the use of miniature, high-pressure, turbine-powered jet engine simulators to produce scaled inlet and exhaust nozzle flows simultaneously. These 3-in. diam mini-engines can simulate inlet and nozzle flows for engine pressure ratios (EPR) in excess of 3.6:1 and are known as CMAPS (compact multimission aircraft propulsion simulators). The first wind-tunnel test using two of these miniature engines to simulate complete propulsion effects on a V/STOL fighter configuration will be completed soon. The objective of this test is to measure the differences in airframe/propulsion system interactions produced by conventional (flow-through and jet-effects) and CMAPS test techniques. Test of the conventional flow-through and jet-effects modes in the 11-Foot Transonic Wind Tunnel was completed in June 1982. Baseline data were obtained at Mach 0.4 to 1.4 and for angles of attack from -2° to 240°.

Airflow calibrations of the three NASA CMAPS engines at several values of ambient pressure were completed during the spring and summer of 1982.

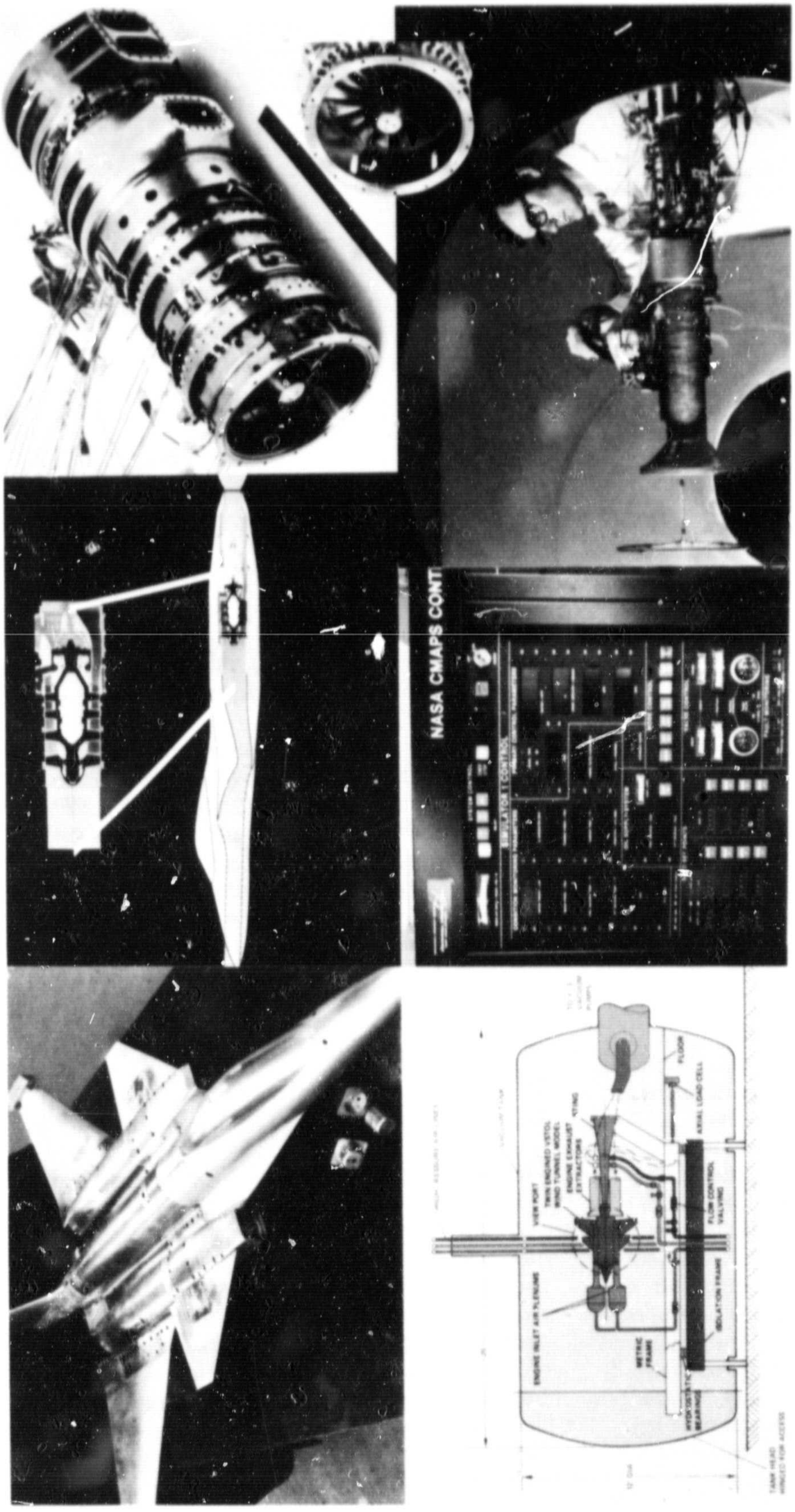
Maximum utility of the new test tool in supersonic aircraft configurations will require thrust and airflow calibrations with the CMAPS installed in the models. The Propulsion Simulator Calibration Laboratory (PSCL) is being developed to permit this type of calibration. This facility is unique in that it will produce simultaneous calibrations of installed net and gross thrust at inlet and nozzle ambient pressures that duplicate wind-tunnel ambient conditions.

(R. Bailey, Ext. 5990)

Prop-fan Installation Aerodynamics

Tests on a powered, semispan model of an advanced transport with wing-mounted, prop-fan propulsion are continuing as a part of the NASA Advanced Turboprop Program. Experimental determination of installed prop-fan propulsion characteristics is needed to support early projections of the magnitude of the prop-fan benefits.

Preliminary wind tunnel tests conducted at Ames in 1981 indicated that a conventional nacelle on wing installation led to unacceptable drag levels because of adverse interference with



Propulsicn airframe integration research at Ames Research Center

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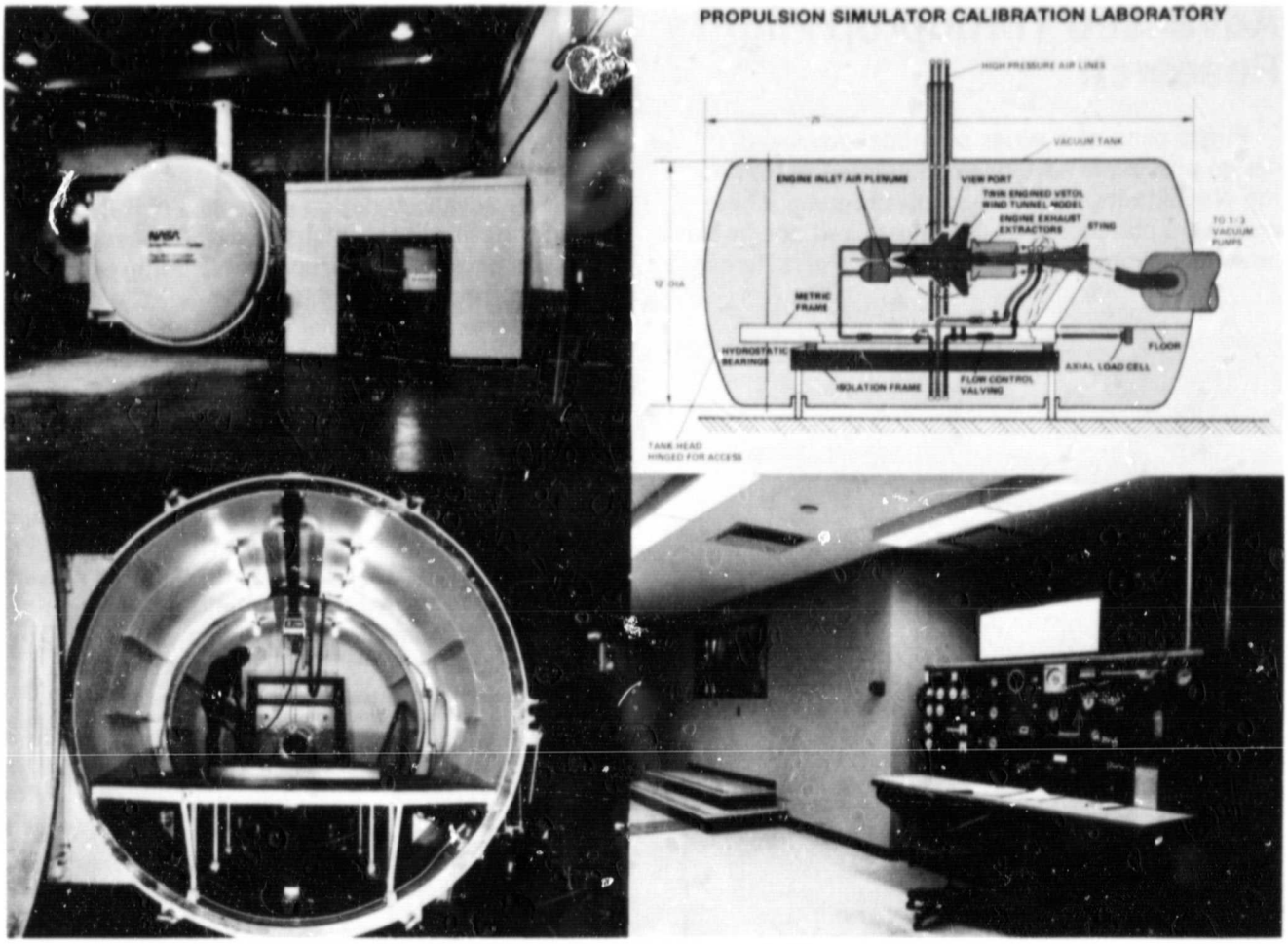
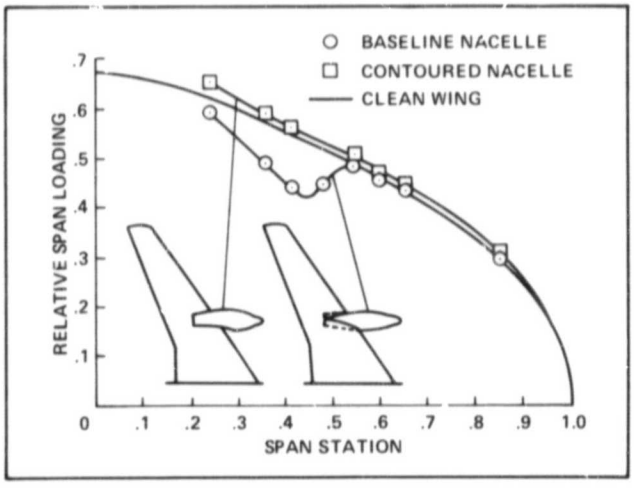


Propulsion simulation calibration laboratory at Ames Research Center

the wing supercritical flow field. Since then, use of diagnostic techniques, such as color-graphics-generated pressure contours and fluorescent oil-flow visualization has helped to explain these strong interactions. These methods and state-of-the-art flow codes were used by Douglas Aircraft Company/Long Beach to redesign the wing and nacelle contours and significantly reduce the interference drag at the M = 0.8 cruise condition. The modified airfoil sections between the nacelle and fuselage eliminated a shock-induced separation caused by the combined nacelle and propeller slipstream-flow disturbance on the upper surface of the wing. In addition, a lift loss induced by the nacelle was eliminated by reshaping the nacelle contours. This was accomplished by changing the lines of the nacelle to closely resemble the streamlines of the flow over the wing without a nacelle. A third source of high drag was traced to the corner flows at the wing-nacelle junctions. This source of installed-nacelle drag was substantially reduced by developing fillets at the junctions.

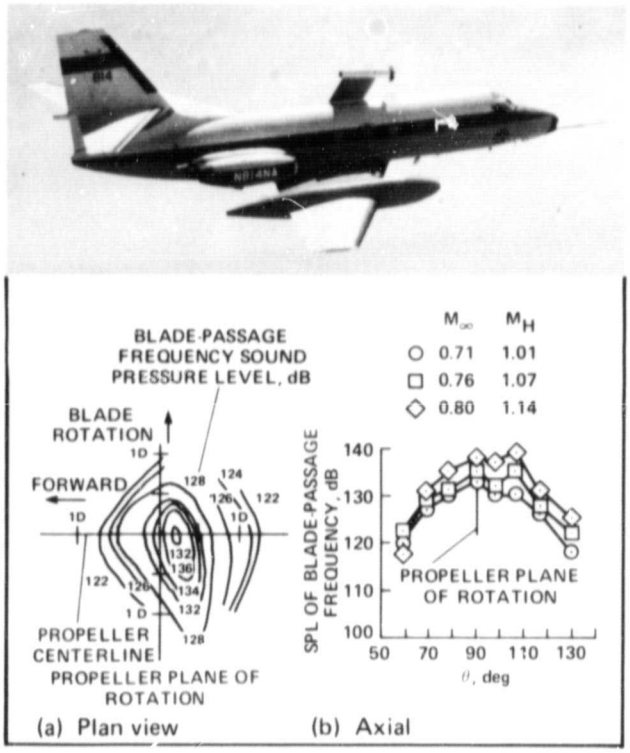


Span loadings for two wing-mounted, prop-fan nacelle installations

(R. Smith, Ext. 6113)

Advanced Turboprop Flight Research

Flight tests of a series of model advanced-design propellers have been conducted as part of the NASA advanced turboprop program. These tests were conducted to investigate and document near-field acoustic characteristics of the different



(a) Blade-passage frequency sound pressure level contour: altitude = 30,000 ft, $M_\infty = 0.76$

(b) Measured in-flight sound pressure level directivity of blade-passage frequency on fuselage ahead of and aft of propeller plane

design propellers. The results are needed to establish near-field acoustics and provide information for designing larger-scale propellers.

The JetStar was modified for the advanced-design propeller experiment by mounting a pylon on top of the fuselage and installing an air-turbine drive motor and its associated plumbing. An array of flush-mounted microphones was located on the fuselage under the propeller for making the acoustic measurements. Boundary-layer rakes were installed on the fuselage under the propeller plane to determine the flow field in the boundary layer. An airspeed boom was also flown at the propeller location to accurately determine the Mach number and flow angularity. For later acoustic flights, a microphone boom was mounted above the propeller to acquire acoustic data free of fuselage boundary-layer effects.

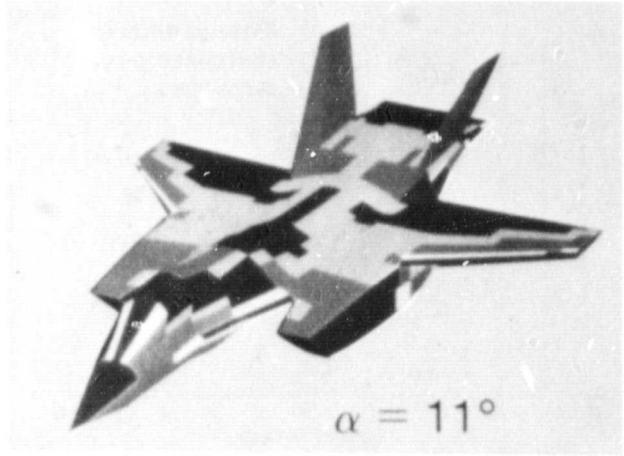
Three advanced-design propellers (SR-2, SR-3, and SR-6) have been flight-tested. Acoustic data analysis of the three propellers is being undertaken at three NASA centers.

A representative blade-passage, sound-pressure-level contour of SR-3 is shown. The blade-passage frequency was 954 Hz with a helical tip Mach number of 1.07. The axial directivity of the blade-passage frequency for a propeller advance ratio is 3.12 and propeller blade angle is 59.3°. The data presented are for three airplane Mach numbers, M_∞, which result in helical tip Mach numbers, M_H, of 1.01, 1.07, and 1.14. The noise levels tend to decrease more rapidly forward of the propeller plane than aft of the propeller. Detailed comparisons between flight, wind tunnel, and theoretical predictions are being made.

(P. Lasagna, Dryden Ext. 364)

Color Graphics in Aerodynamic Analyses

The shaded photographs of the Grumman Model 623 V/STOL fighter concept are representative of the use of color graphics in aerodynamic analyses. Since there are large amounts



PANAIR visual aerodynamics

of aerodynamic data being collected from both measurement and computational sources, rapid means of interpreting the data are needed. Pressure coefficients were calculated from a paneling method at Mach 0.6 and three angles of attack. The pressures are displayed directly on a mathematically defined aircraft geometry. The regions of high pressures are represented by red (darker shades in black and white photo); blue represents low pressures.

(J. Cozzolongo, Ext. 6134)

Hidden-line Solution for Three-dimensional Computer Graphics

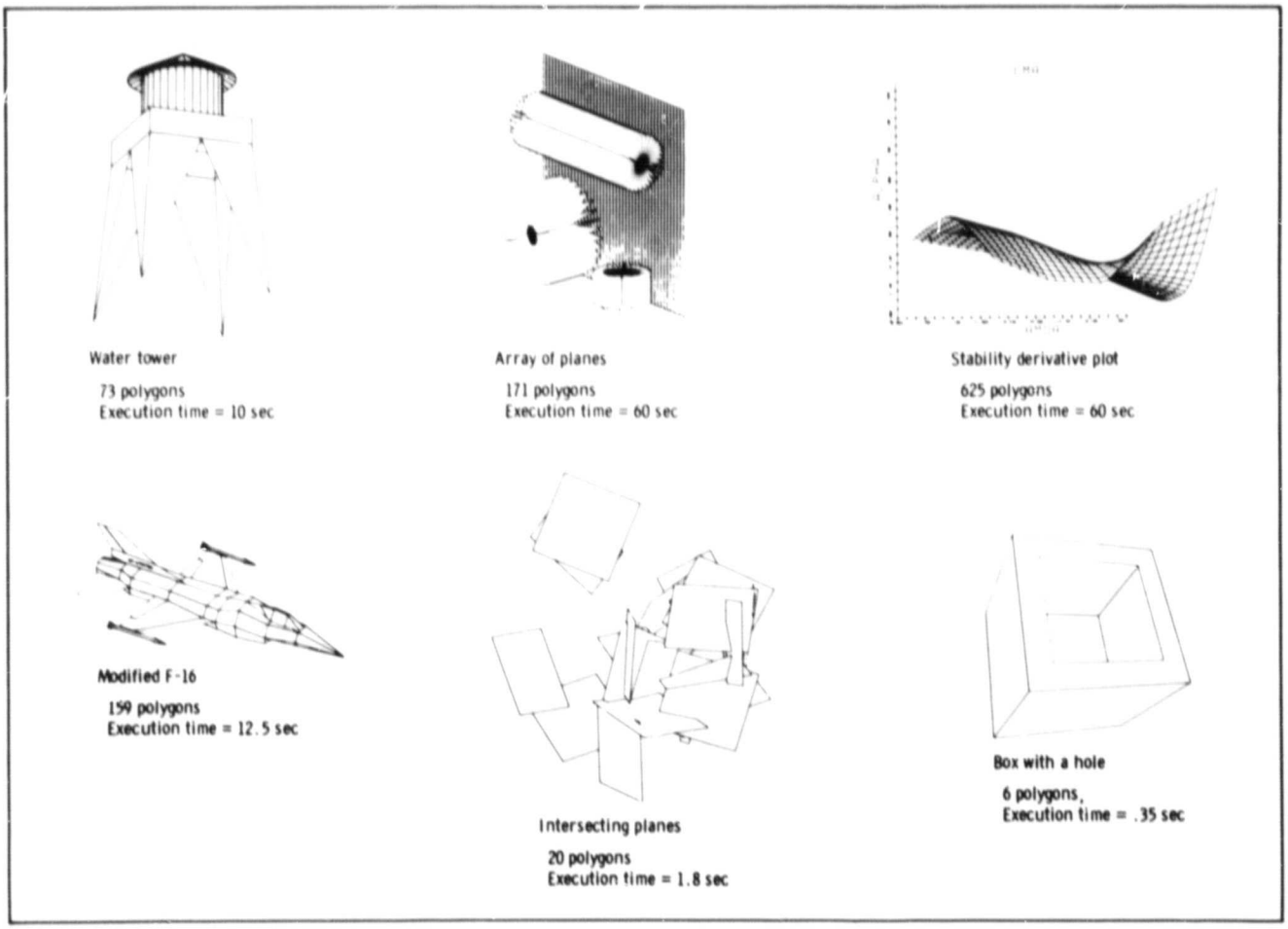
A novel solution to the hidden-line problem associated with three-dimensional presentations was recently published. An algorithm based on this theoretical presentation was implemented and descriptive software was developed.

Compared to other existing approaches, the algorithm is both general and efficient. Its superiority to the industry standard (Watkins' algorithm) has been verified at Los Alamos National Laboratory and Livermore Laboratory. Moreover, the algorithm enjoys linear growth up to the number of polygons tested. A reasonably dense set of 20,000 polygons was portrayed in approximately 45 sec on a Cray 1S computer.

Because of its generality, applications are broad and are being used for aerodynamic and structural modeling, space physics, simulation, etc. Many of the applications are in a real-time and interactive environment.

The computer program has been released by Cosmic and the initial feedback from users in private industry, government, and the academic community has been enthusiastic.

(D. Hedgley, Dryden Ext. 227)



Computer-generated line drawings

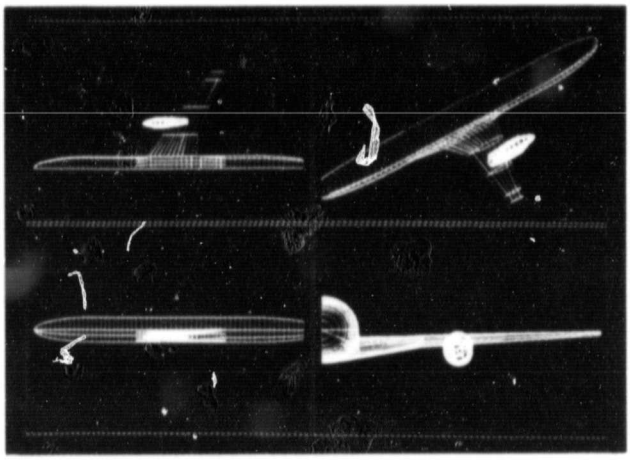
Computer-aided Design and Manufacturing

A computer-aided design (CAD) system is being used at Ames to generate aircraft geometry for aerodynamic analysis and to fabricate wind-tunnel model parts. The CAD system provides the capability for constructing three-dimensional geometric models with the advantage of using a common data base from which to generate the input for panel method codes and to define numerical control (N/C) tool paths.

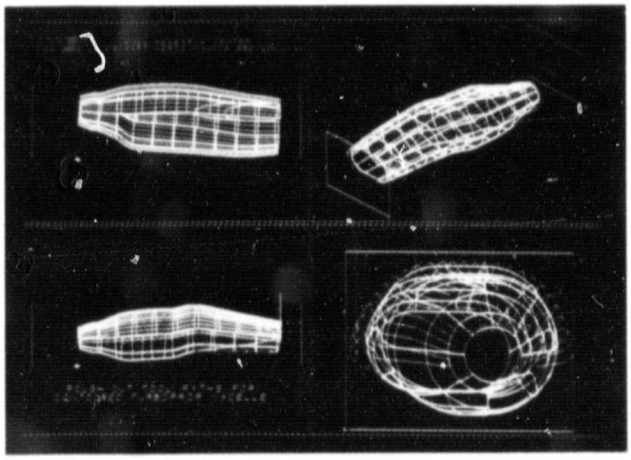
The CAD system proved to be a significant aid in generating the geometry for the advanced turboprop wind-tunnel model. In a matter of seconds, the system calculated complex surface intersections such as between the wing and nacelle. An interactive program was written to generate the analysis input points on the model surfaces, allowing the user to choose several types of point distribution methods. The task of analyzing different configurations was easily accomplished using the system's geometry-editing and model-merging capabilities.

Numerical control tool paths were generated on the CAD system to machine a contoured wooden nacelle for the turboprop model. This will be used as a mold in the fabrication of fiberglass shells for the turboprop wind-tunnel model. Reference curves, such as the wing-nacelle intersection, were also cut onto the surface using N/C tool paths generated from the geometry data base. The CAD system will be used in defining N/C tool paths for other parts of the turboprop wind-tunnel model, including a new wing design.

(F. Enomoto, Ext. 6133)



3-D configuration of turboprop wind tunnel model



N/C tool paths of contour nacelle

Curved Surface Modeling for Computer-generated Graphics Data Bases

A vital aspect of Computer-Generated Imagery (CGI) systems is the primitive descriptor(s) that must be used to define the visual scene, collectively referred to as a data base. Present technology uses dots, lines, and polyhedrons. Special techniques such as smoothing and shading are then applied to make the surface appear smooth and continuous.

A direct result of our in-house research over the past several years is the derivation of a fundamental geometry algorithm, a development that is currently unique to NASA-Ames. The algorithm results in the determination of higher-ordered mathematical descriptors capable of faithfully representing the shape of CGI objects via curved surface patches, and thus avoids the problems inherent in current polyhedral descriptions. The derivation-of-geometry algorithm resulted from fundamental theoretical mathematical considerations, and hence promises to be both powerful and comprehensive. The algorithm has the ability to faithfully represent the geometry of two- and three-dimensional objects. Given this fundamental geometry algorithm, coupled with texture

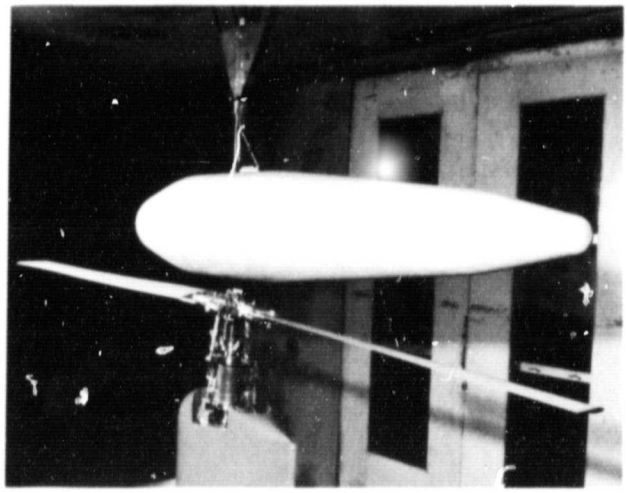
descriptors integral and functionally dependent on surface geometry, the capability for high-fidelity representation of contours and sufficient velocity and attitude cue generation is possible.

(H. Hoy, Ext. 5646)

Helicopter Rotor/Body Interactions

An experimental investigation was conducted in the Ames 7- by 10-Foot Wind Tunnel to obtain quantitative measurements of the steady-state aerodynamic interactions occurring in a simplified helicopter system consisting of a rotor and a body of revolution. These data provided a data base for correlation with an improvement of analytical techniques, qualitative information about interaction trends applicable to full scale, and some insight into the aerodynamic mechanisms that cause these interactions.

Current analytical techniques permit fair success in predicting the performance of an isolated rotor or an isolated fuselage, but fail to accurately predict the performance of a complete helicopter system. Each component of the helicopter interacts with each of the other components such that detailed characteristics of the flow field are dependent on the entire system. While the details of this complex flow field may be the ultimate goal of helicopter designers, their effects on performance, loads, and vibration are of more immediate concern.



One-sixth-scale rotor and body

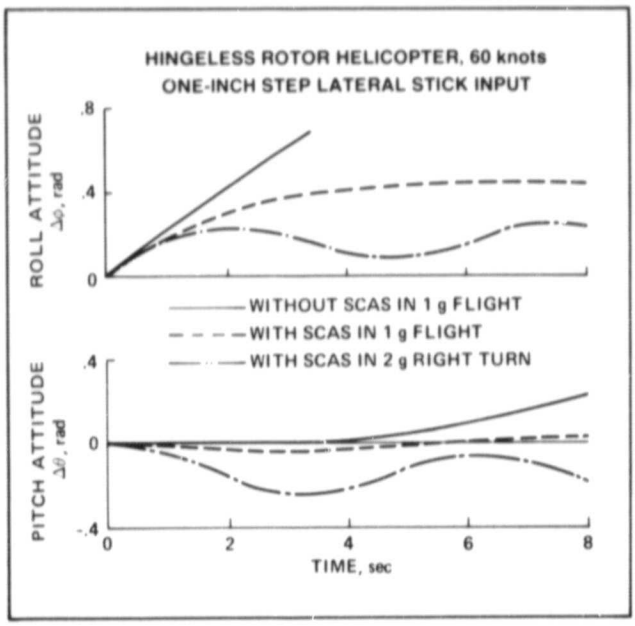
The interaction of the body on the rotor performance and the effect of the rotor on the body aerodynamics were determined for variations in velocity, thrust, tip-path-plane angle of attack, body angle of attack, rotor/body position, and body nose geometry. Significant conclusions were:

1. A body of revolution near the rotor can produce significant favorable or unfavorable effects on rotor performance, depending on the operating condition.
2. Advance ratio, body angle of attack, rotor/body separation, rotor/body longitudinal relationship, and body nose shape have a strong influence on the interaction of the body on the rotor.
3. Longitudinal aerodynamic characteristics of a body of revolution are significantly modified by the presence of an operating rotor and hub; the hub may be a major source of this interaction.
4. Full-scale rotor performance data obtained by using a body of revolution in a wind tunnel may be significantly affected by the rotor/body interaction effects.

(M. Betzina, Ext. 6679)

Flight Dynamics of Rotorcraft in Steep High-G Turns

An analytical procedure has been developed to permit a systematic investigation of rotorcraft flight dynamics in steep high-g turns. Numerical examinations of a tilt-rotor aircraft and three single-rotor helicopters with different types of main-rotor systems have been conducted. It has been found that strong coupling exists, particularly at low speeds, in longitudinal and lateral-directional motions in high-g turns for both the symmetrical- and asymmetrical-type rotorcraft; flying-qualities and flight-control design analyses based on small disturbances from straight flight are grossly inadequate for predicting flight dynamics in high-g maneuvers. For example, for single-rotor helicopters the direction of turn has a



Effect of load factor on control response of augmented rotorcraft

significant influence on the flight dynamic characteristics in high-g turns, specifically, a high-g right turn tends to stabilize the spiral mode, and a left turn destabilizes it to develop an unstable spiral mode. On the other hand, a right turn tends to destabilize the longitudinal phugoid mode, and left-turning flight stabilizes the phugoid. Furthermore, the longitudinal heave mode and the spiral mode tend to merge to yield a stable oscillatory mode in high-g turns.

An evaluation of a stability and control augmentation system (SCAS) has also been conducted to examine its performance in high-g turns. The results show that the stability and control response characteristics of the aircraft with the SCAS, which otherwise performs satisfactorily in flight near 1 g, becomes significantly degraded in steep turning flight. It is imperative, therefore, that due attention be paid to the SCAS design, properly accounting for the variations in flight dynamics with load factor, to ensure that the system will perform satisfactorily, not only for operations near 1 g but also in high-g maneuvers, if the rotorcraft system is intended for missions requiring frequent excursions to the edges of its maneuvering flight envelope.

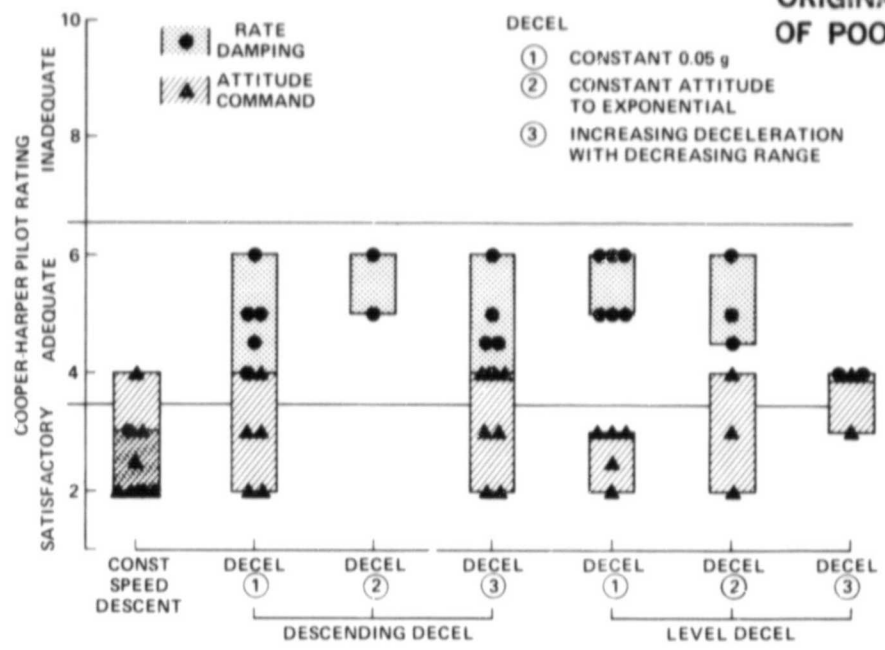
(R. Chen, Ext. 5008)

Certification Criteria for Helicopter Decelerating Instrument Approaches

To exploit the unique capabilities of helicopters, it is desirable to consider decelerating approaches to permit operations in visibility conditions reduced below those for current operations. It is necessary to understand the implications of such operations for the flying qualities of the helicopter so that the Federal Aviation Administration (FAA) can determine appropriate airworthiness requirements. A ground-based simulation experiment has been conducted in conjunction with the FAA to determine certification criteria for helicopter decelerating approaches in instrument meteorological conditions. The experiment examined the influence of stability-control augmentation, display information format, and approach profile on flying qualities for precision terminal-area operations.

It has been found that decelerating approaches on instruments (from 60 to 15 knots at breakout) were not significantly more difficult to perform than a precision, constant-speed approach. Furthermore, very little difference in flying quality requirements was observed for a variety of deceleration profiles ranging from steep descents to level flight. As with constant-speed approaches, attitude command augmentation in pitch and roll provided marginally satisfactory flying qualities in all cases, whereas rate damping augmentation alone provided only marginally adequate flying qualities. Conventional mechanical displays that incorporate a three-cue flight director are sufficient to achieve adequate flying qualities.

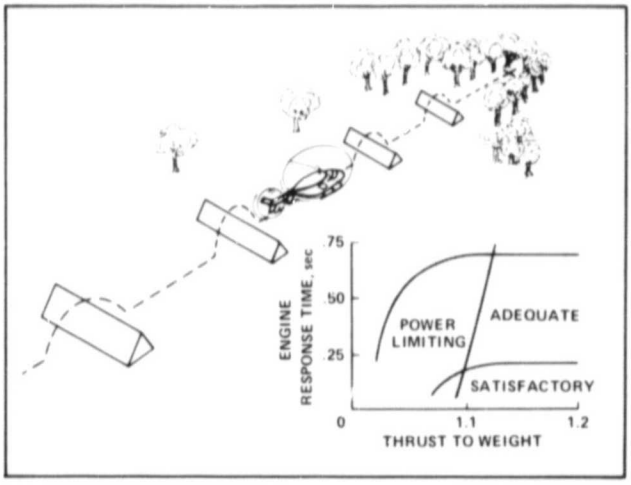
(J. Lebacqz, Ext. 5272)



Pilot rating results as function of task

Effects of Engine Response, Excess Power, and Airframe Dynamics on Flying Qualities for Nap-of-the-earth Operations

The potential for improving helicopter flying qualities through the use of electronic fuel-control devices on helicopter gas turbine engines has led to the study of effects of engine dynamics on height control during nap-of-the-earth operations. An understanding and quantification of these effects is essential for the exploration of such controls. Ground-based simulation experiments have been conducted on the Vertical Motion Simulator to evaluate a range of engine dynamics, vehicle height control dynamics, and excess power characteristics for this purpose. Results of these experiments show several areas in which present flying qualities specifications require extension or modification. Engine governor dynamic response and the tradeoff between engine/governor response and excess power requirements have been defined for precision vertical maneuvering tasks and are the basis for the extension of existing specifications. Modifications of existing criteria for vertical velocity damping and collective control sensitivity are also indicated.



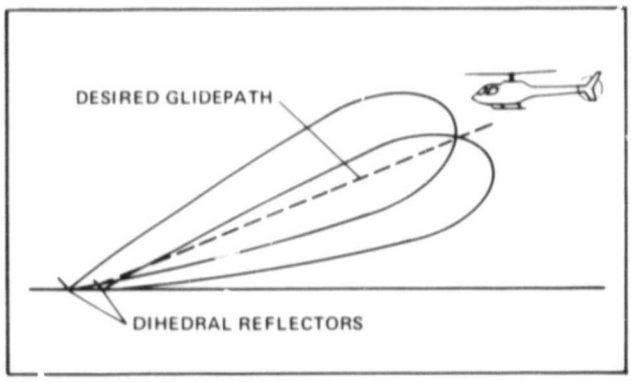
Nap-of-the-earth operations

(L. Corliss, Ext. 6115)

Helicopter Airborne Radar Approaches

As a first step of a research program to investigate the potential for high-resolution radar approach and landing systems, a flight-test program was completed to determine the imaging capability of a high-resolution radar for typical helicopter landing sites. The test was performed in cooperation with the Army, using a 95-GHz, millimeter radar system mounted aboard an Army UH-60 Blackhawk helicopter. Based out of Eglin Air Force Base, Florida, four sites typical of helicopter landing environments were imaged: (1) off-shore oil rigs in the Gulf of Mexico, (2) a medium-size heliport facility with 25 concrete landing pads, (3) an aircraft carrier, and (4) the runway environment at Eglin. Although the results of this flight-test program are still being analyzed, preliminary data show that helipads are distinguishable to trained radar operators at ranges up to 400 m. At that range, an aircraft on the helipad is easily distinguished. Currently, studies on a variety of image-enhancement techniques are in progress to ease identification of helipads and improve the potential for using a high-resolution radar for primary approach and landing guidance.

In another program, Ames has continued investigation of commercial weather/mapping radar for helicopter instrument approaches to remote sites. After a successful program with the University of Nevada to detect ground-based corner reflectors in a high-clutter environment, a follow-on program has completed initial test of a system which will provide a pilot with precision localizer and glide-slope information using an airborne weather radar and a ground-based beacon or reflector array. Using an on-board microprocessor add-on to a conventional weather radar, radar return from beacon antennas or radar reflectors are processed to provide precision guidance information. The figure shows how the radar return patterns are overlapped to provide an aircraft with glide-slope information. By measuring the return from both reflectors, the microprocessor is able to determine if the aircraft is above or below the intended glidepath and display that information to the pilot on a conventional glide-slope display.



Use of a pair of tilted dihedral reflectors to define glide-slope; comparison of received signals from reflectors determines aircraft elevation.

(G. Clary and D. Anderson, Ext. 5452)

Helicopter Satellite-based Navigation

The future use of Navstar global positioning system (GPS) by the civil helicopter community promises enhanced performance not available with current navigation systems. GPS will provide properly equipped users with extremely accurate three-dimensional position and velocity information anywhere in the world. Helicopter missions, including off-shore exploration, low-altitude transport into remote and mountainous terrain, and approaches into noninstrumented landing sites, need accurate altitude above the terrain or above mean sea level. Analytical studies and field tests have shown that the vertical measurement of position from GPS is the poorer of the measurements available. Analysis of the geometric relationship between the satellites and the receiver show that, on the average, the vertical component of error will be almost twice as large as the horizontal components of error. Barometric altitude aiding has been shown to improve the vertical position estimate, but differential GPS techniques appear to provide an order of magnitude performance increase.

Analytical and experimental techniques are being used at Ames to obtain a better understanding of this critical problem. Static laboratory tests with a GPS receiver have documented the poor vertical performance. A series of in-flight tests were designed and conducted in the NASA SH-3G helicopter to obtain data on the relative performance of the four-satellite versus the barometric

altitude-augmented, three-satellite mode of operation of the GPS receiver. Data analysis of the relative performance of the two configurations is in progress and will provide additional insight.

(F. Edwards, Ext. 5437)

Rotor Systems Research Aircraft

The Rotor Systems Research Aircraft (RSRA) have completed engineering checkout and are operational at Ames Research Center. The two aircraft, one in the helicopter configuration and one in the compound configuration, are being used to obtain research data while their systems development is being completed. Each aircraft contains unique force and moment measurement systems which allow acquisition of flight data not previously obtainable. The aircraft also have electronic flight control systems (EFCS) which allow unprecedented control of test conditions, and an emergency blade-severance and crew-escape system. The compound aircraft has a full complement of both rotary-wing and fixed-wing flight controls and a variable-incidence wing, and is designed to be capable of flying without the rotor. The goal of the RSRA flight research program is to investigate new rotor design methodology and verify new rotorcraft technology. This is possible by replacing the existing S-61 rotor with new advanced-technology designs.

Compound Configuration Rotor Systems Research Aircraft

During the past year the compound aircraft flew 27 flights, including the government pilots' checkout and development of flight procedures and techniques to reduce stabilator vibratory loads which had previously grounded the aircraft. Of particular significance, the incidence of the wing was controlled between 0 and 10° in flight for the first time, allowing variation of rotor thrust at a given airspeed.

The helicopter configuration was flown to obtain, for the first time ever in flight, down load in the wake of the hovering rotor using the unique rotor-force-measurement system. Parameter identification data for stability and control analysis and structural data on the empennage were also obtained with the helicopter. The EFCS is being flight-tested on the helicopter, and the compound aircraft is undergoing a shake test as a prelude to a dynamic calibration of the force measurement system for measuring vibratory rotor loads.

(J. Burks, Ext. 6576)

XV-15 Tilt Rotor Research Aircraft

This was a very important year in the history of tilt-rotor technology. The concept was widely exhibited to the aerospace community using one of the XV-15 aircraft; the other XV-15 was used primarily to continue exploring performance limits and detailed handling qualities. The XV-15 used for the technology demonstrations was operated by Bell Helicopter Textron, Inc., for Ames

XV-15 in camouflage paint

Research Center. Three general categories of demonstration work were performed: familiarization flights for guest pilots, flight demonstrations performed by project pilots using variations of the Paris Airshow routine, and military mission evaluations at off-site military installations.

More than 40 pilots flown as guests in the XV-15 included Senator Barry Goldwater of Arizona, Navy Secretary John Lehman, General Officers, and numerous operational pilots. All of the guest pilots were favorably impressed with the handling qualities of the aircraft, particularly with the low workload involved in conversions and reconversions from helicopter to fixed-wing mode. The highlight of the demonstration tour was the exhibition at Fort Rucker where the XV-15, Advancing Blade Concept Aircraft (ABC), and the Apache (YH-64) were demonstrated to a select audience of more than 50 General Officers from all of the military services who were attending the Army Aviation Systems Program Review.

The military mission evaluation work performed this year included the execution of numerous Special Electronic Mission Aircraft (SEMA) missions in a simulated combat environment at Fort Huachuca, Arizona, flying against ground-threat simulators. On August 2, 1982, the XV-15 became the first tilt-rotor aircraft in history to land aboard a naval vessel when it landed aboard the U.S.S. Tripoli (LPH-10). During the demonstration work, 54 landings and takeoffs including short takeoff and landing (STOL) takeoffs were executed. This work demonstrated that deck-edge effects and downwash/outwash problems with deck handling were negligible, and that tilt rotor aircraft are compatible with a shipboard environment. During the military mission work, the XV-15 demonstrated a reliability that surpasses that of many operational aircraft. During a year's operation, the aircraft completed 171 of 179 scheduled flights for a reliability of 96%. Most aborts were due to research instrumentation problems or electronics component failures, and none was concept related.

XV-15 lands aboard U.S.S. Tripoli

The aircraft posted a number of new performance milestones during the year. STOL operations were conducted at 15,000 lb gross weight, and the aircraft was hovered in ground effect at that weight (maximum rated hover gross weight is 13,000 lb). The aircraft was flown to a density altitude of 25,500 ft and to true airspeeds of 301 knots in level flight and 345 knots in a shallow dive.

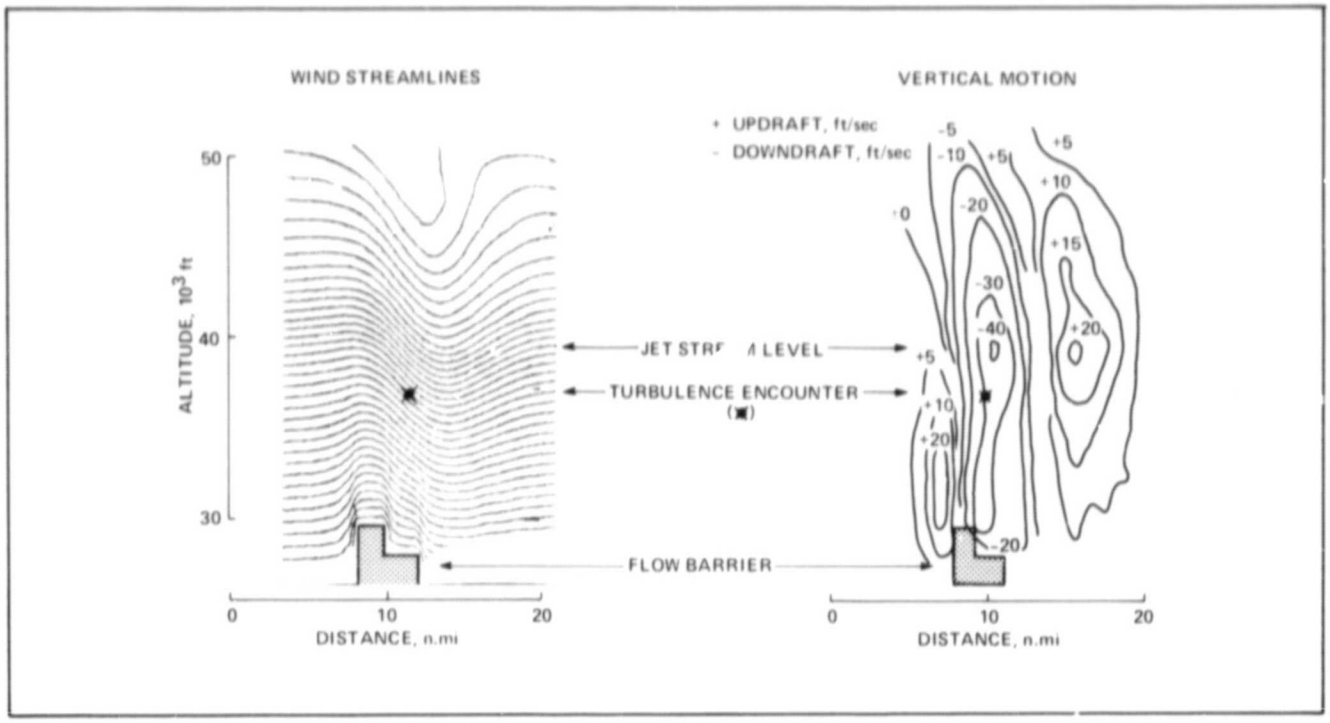
The activities of the past year have proven that the tilt-rotor technology is mature enough to support full-scale development of this concept, and a joint services concept evaluation study team has concluded that the tilt-rotor aircraft is a viable candidate for the present Joint Interservices Vertical Lift Aircraft Development program planned to be operational in the 1990s by the Marines, Army, Navy, and Air Force.

(J. Magee, Ext. 5020)

Numerical Simulation Studies of Atmospheric Wave Motion

Gravity waves resulting from flow over mountain topography or active thunderstorm cumulus clouds in the troposphere trigger much of the strong, clear air turbulence encountered by aircraft. Analytical solutions for these wave actions are limited to idealized structures of the atmospheric wind and temperature profiles. Numerical simulation studies accomplished under a grant to the University of California have shown that wave behavior of actual atmospheric structures can differ markedly from the behavior expected on the basis of previous analyses.

Results from the use of the numerical simulation code to study a case of strong, clear air turbulence encountered by a transport aircraft above a storm line developing at lower altitudes are shown. The simulations, which used a barrier in



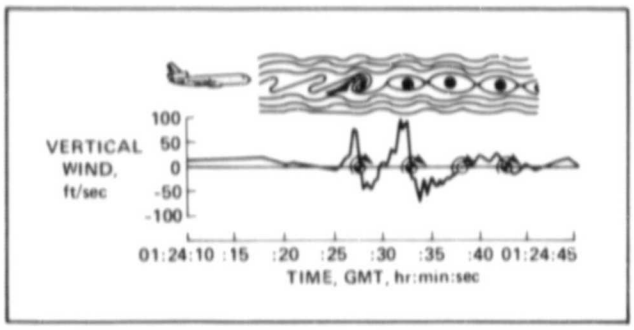
Numerical simulation of atmospheric wave motion caused by a cumulus barrier

the middle troposphere to represent the flow blocking caused by a developing thunderstorm line, show that significant vertical motion is generated in a large region of the atmosphere. Streamlined and vertical motion velocity fields in a vertical cross section of flow over the barrier are also shown. The flight altitude of the turbulence encounter was just below the troposphere and the level of maximum jet stream wind speed. In this region the simulation model showed that wind shear increases and dynamic stability decreases to create conditions for Kelvin-Helmholtz instability and the resulting strong turbulence, as experienced by the airplane. Numerical simulations of this type can improve our understanding of the atmosphere and our ability to avoid hazardous turbulence.

(L. Ehrenberger, Dryden Ext. 435)

Analysis of Clear-air Turbulence Encounters

Turbulence upset is a continuing problem that must be better understood in the interest of airline operational safety. One way to investigate the nature and cause of turbulence is to analyze flight data obtained during airline encounters with severe turbulence. In the past, most flight data were obtained from the metal-foil recorder carried by narrow-body jet airliners, but that recorder does not contain enough information to permit an adequate determination of wind characteristics. Modern wide-body airliners, however, are equipped with a digital flight-data recorder (DFDR) that, together with ground-based air traffic control (ATC) radar records, does provide



Reconstruction of turbulence encounter at 37,000 ft over Missouri (April 3, 1981)

sufficient data to determine winds. Advanced data-analysis methods, developed at Ames in support of the National Transportation Safety Board, are applied to extract the desired winds.

One recent incidence of turbulence upset involved a DC-10 aircraft cruising at about 37,000 ft near Hannibal, Mo., in April 1981. An analysis of the available DFDR and ATC data indicates that the aircraft encountered a series of discrete horizontal vortices. This phenomenon appears to be a type of air motion, called "cat's eye" vortices, theoretically associated with unstable (horizontal) shear layers in the jet stream, which, in this case, probably developed over a local storm front. Although the cat's eye vortex phenomenon had been previously hypothesized as a possible clear-air turbulence hazard, the Ames analysis provides the first real evidence of its existence as a cause of a high-altitude turbulence upset.

(R. Bach, Ext. 5429)

Flightpath Optimization

This research seeks to develop concepts and computational algorithms for automated on-board systems that generate various types of optimal trajectories for civil and military applications. Earlier research has culminated in the development of algorithms which industry has incorporated in commercially available flight-management systems, including those in the Boeing 767/757, DC-10, and C141 aircraft. These "first generation" algorithms optimized trajectories with respect to fuel consumption and operating cost during climb-cruise-descent along specified horizontal paths. Research completed in FY 1982 has developed new and more versatile algorithms applicable to a wider range of operational conditions as well as to additional aircraft types.

One such extended algorithm simultaneously optimizes the curved ground track near take-off and landing and the climb-cruise-descent segments. The resulting on-board trajectories will therefore be more nearly optimum in three-dimensional space rather than being limited to the vertical plane as in previous cases. Another extension of the algorithm generates minimum fuel trajectories when the pilot specifies a delay in the landing time. The algorithm seeks the combination of speed/altitude change and horizontal path stretching so as to minimize fuel consumption for a specified delay time. These extended algorithms involve only software modifications and therefore can be implemented in the flight management systems now entering commercial service.

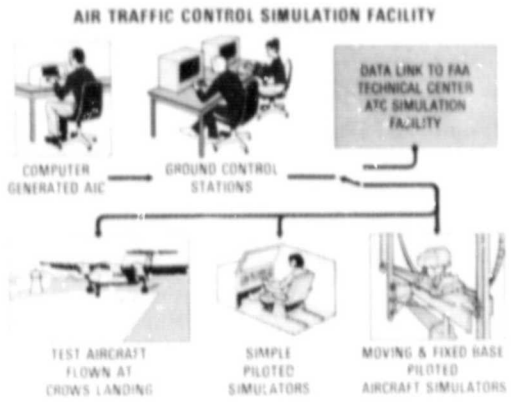
In the area of air-combat flightpath management, a new analytical technique, with roots in the theory of differential games, is yielding an algorithm for solving optimal pursuit and evasion problems. A computer simulation of the algorithm generates optimal trajectories for variable-speed games in the plane. Extension to a feedback solution implementable on board appears feasible.

An algorithm was also developed for flightpath optimization of helicopters. As oil and gas exploration extends farther over the ocean, the maximum range of helicopters, widely used in servicing oil platforms, becomes an important limitation. Analysis has shown that on-board trajectory optimization can help to extend that range.

(H. Erzberger, Ext. 5450)

Automated Flow Management Concepts

The air-traffic-control system stands at the threshold of massive change that will cost billions of dollars and take over a decade to complete. The central theme of this change is the extensive use of computers to automate complex decision processes on the ground and in the air. At Ames, research in air traffic control is concentrating on



Air Traffic Control Simulation Facility

concepts and computer algorithms for automating air-traffic-flow management in a complex terminal area.

In FY82 two noteworthy results were achieved. First, a ground-based scheduling algorithm was defined for assisting the controller in assigning conflict-free and precisely spaced landing times to a complex mix of arrival traffic. The scheduling algorithm responds to a multitude of constraints and conditions such as: (1) type, weight, size, and airspeed profile of aircraft, and (2) type of on-board avionics such as an advanced four-dimensional flight management system. Based on these and other inputs the algorithm creates an efficient sequence of departure times for all aircraft from the feeder fixes, which are the starting point for flight in the terminal area. An important attribute of the design is the ability of the controller to interact with the computer algorithm and to modify the automatically generated schedules as needed.

The second accomplishment in FY82 was the implementation of this algorithm in the Air Traffic Control Simulation Facility at Ames. This facility, used extensively during the last 7 years, allows evaluation of complex ATC procedures and guidance algorithms in real time, with both controllers and pilots as participants. For each aircraft (up to 30 simultaneously) flying in the simulated terminal area, the simulation contains comprehensive models of dynamic performance and on-board guidance and navigation systems. A series of simulation experiments, conducted jointly with the FAA, is in progress to evaluate this algorithm.

(L. Tobias, Ext. 5451; H. Erzberger, Ext. 5450)

Head-up Displays in Transport Aircraft Applications

A NASA/FAA program seeking to define the effectiveness of head-up flight-control and guidance-display concepts (HUD) in the approach and landing of civil transport aircraft has been completed. FAA flight evaluations of one of the HUD concepts in a 727 airplane was conducted in which a "flightpath" display format, using INS-derived attitude and inertial path measures, was evaluated by nine FAA and NASA pilots. The pilots expressed a strong appreciation of the precision of flightpath control offered by the flightpath symbology, both in landing operations and en route. Day and night operations exposed no significant difficulties in the use of the combiner unit and its collimated display. All flights were made in clear weather, but "hooded" approaches were conducted to Category I minimum altitudes (200 ft).

A final simulator experiment was conducted with the primary objective of evaluating HUD in an area of operations excluded from the scope of the original program; that is, Categories II and III automatic and manual landings. Five air-safety representatives of the Air Line Pilots Association, and five pilots representing the Air Transport Association compared the head-up display with conventional displays in low visibility scenarios involving meteorological or control or guidance system anomalies. Additional scenarios presenting challenging wind shear and visibility aberrations in Category I and nonprecision approaches were flown to complement the experience of the previous simulator experiments. All pilots considered the flightpath HUD effective and free of inherent problems other than the obvious training requirements. Their opinions of the value of the HUD in

landing approach relative to conventional displays generally ranged from "better" to "very superior." Some of the pilots felt that the auto-land monitoring and take-over were particularly enhanced.

R. S. Bray, Ext. 6002)

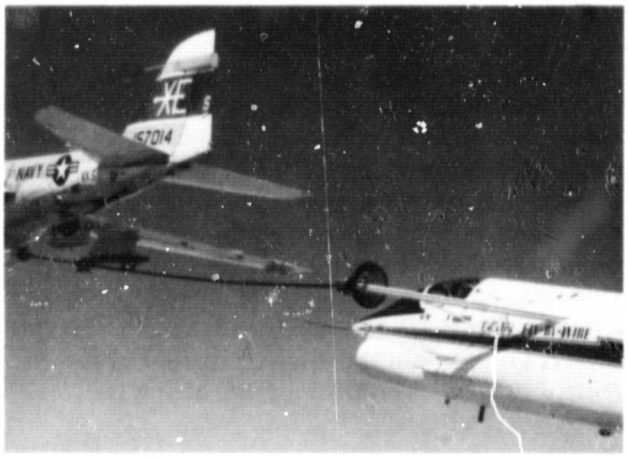
Pilot-induced-oscillation Suppression Filter

Flight tests were conducted using the F-8 Digital Fly-By-Wire (DFBW) aircraft to investigate the effectiveness of software implementable filters designed to detect and suppress pilot-induced-oscillation (PIO). The PIO suppressor filters are designed to eliminate uncontrolled aircraft motions induced by pilot/aircraft or pilot-control system interactions. These uncontrolled motions generally occur when the pilot workload is very high.

The PIO suppressor filters examined are based on designs previously tested at Dryden Flight Research Facility for a different task and are direct descendants of the filters designed for the space shuttle after PIO tendencies were noted in the approach and landing test program. The evaluation task has been improved to allow for higher workloads and better repeatability. The new task is an improved, simulated air-to-air refueling task. It uses a tanker aircraft that trails an air refueling drogue, which was used as a target to provide the high gain closed-loop tracking task to generate a PIO. Additional time delay is an experiment variable and is induced into the control system of the F-8 DFBW research aircraft to ensure a PIO.

The results show the PIO suppressor filters can reduce PIO tendencies for high gain tasks, such as refueling. Based on the results of the current tests, the filter optimal gain selection has been found to be task-sensitive and confirmed the importance of a high workload repeatable task for evaluation.

(J. Stewart, Dryden Ext. 371)

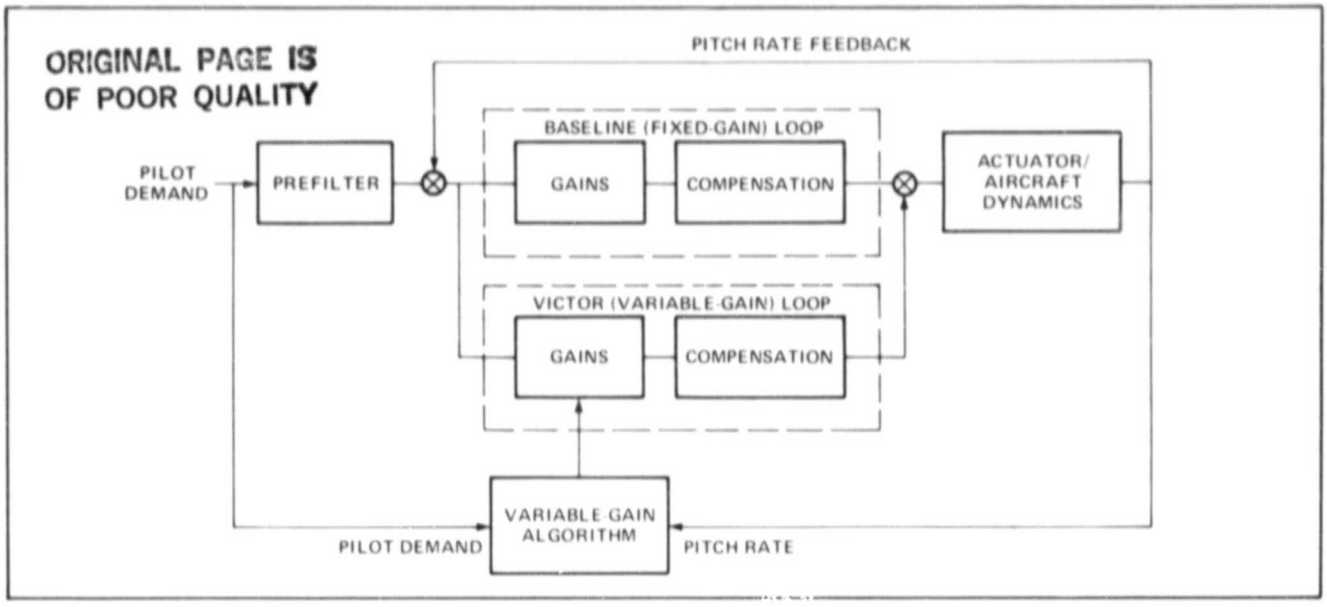


F-8 Digital Fly-By-Wire Research Aircraft engaged in high pilot workload task

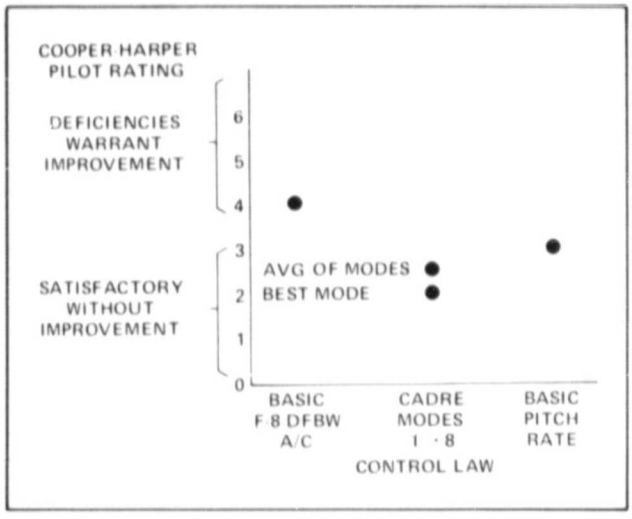
Flight Test and Development of the CADRE Program

A cooperative advanced digital research experiment (CADRE) was established between NASA and the Royal Aircraft Establishment (RAE) in which nonlinear control algorithms developed by the RAE were flight tested on the F-8C Digital Fly-By-Wire (DFBW) aircraft. In the initial phase of the collaboration, some variable-gain algorithms referred to collectively as variable integral control to optimize response (VICTOR) were flight tested. The remotely augmented vehicle (RAV) was selected as the control mode for this experiment because of the already existing RAV interface and the ease of programming, modifying, and testing the algorithms in FORTRAN without disrupting the existing fail-operational integrity of the triplex on-board systems. Also, on-the-fly gain or logical branching options and control mode changes within the CADRE control laws are possible by use of the RAV mode.

The principal aim of the flight tests was to determine whether a variable-gain controller could improve control performance over a linear baseline system, and whether any adverse handling problems were introduced by the rapidly varying gain. The tasks chosen for this assessment were an air-to-air tracking task with the F-8C aircraft required to track an accompanying chase aircraft through a pushover/pull-up maneuver, rapid climbs and descents, and 3-g windup turns. Eight variations of the CADRE control law were



CADRE control laws



Cooper-Harper pilot rating for control laws based on engineering assessment

flight tested. The pilot was asked to assign a Cooper-Harper pilot rating for each of the 8 controllers being tested. The tests have demonstrated that a variable-gain controller can be designed to give improved control performance while maintaining acceptable handling qualities. In addition, they have demonstrated that experimental control laws can be successfully evaluated in flight without undue restriction on the maneuver envelope of the aircraft.

(R. Larson, Dryden Ext. 371)

Dispersed Sensor Processing Mesh

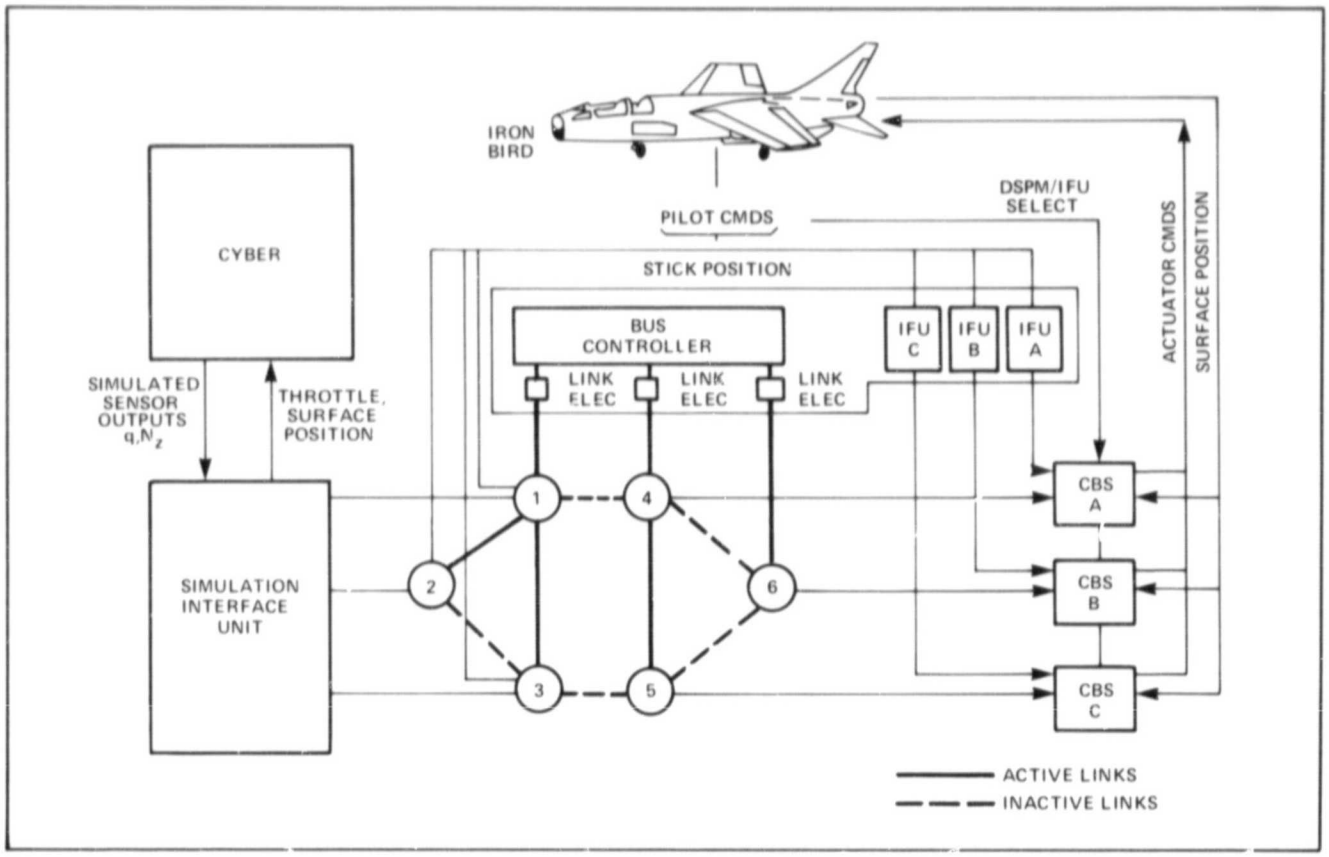
As a follow-on to the F-8 Digital Fly-By-Wire program the dispersed sensor processing mesh (DSPM) experiment is providing an opportunity to apply proof-of-concept work on an advanced data-communication strategy for sensors and effector incorporated into an integrated, digital-control system. The proof-of-concept work in turn is providing insights into the generic problems and contributions of highly reliable communications to digital avionics.

Conventional communication strategy offers only moderate fault tolerance and allows damage to propagate easily. Further, system reliability decreases as the system is expanded. Because of its nodal approach DSPM provides high fault tolerance, limited damage propagation, and easy expansion without severe reliability penalties.

The general objectives of the experiments are as follows:

1. Demonstration of system reconfiguration capability. In particular, the experiment should demonstrate the reconfiguration of flight-critical resources during flight-critical situations, while maintaining acceptable, total aircraft-system performance and safety margins.

2. Demonstration of expansion capability.



DSPM experiment

3. Demonstration of distributed processing capability.

4. Demonstration of components and function distribution of a digital flight-control system.

During 1982, the DSPM system was installed at Ames Dryden Flight Research Facility and system integration was completed. Initial testing revealed some areas of inadequate performance in the Bus Controller hardware and software, and revisions are currently being tested. These revisions will increase the Bus controller throughput and reliability. The results of the performance tests will determine whether the interprocessor communicator will need revision. Systems testing will begin during the fourth quarter of 1982 to measure the performance characteristics of an operational DSPM.

(L. Abbott, Dryden Ext. 551)

Development of a Flight-test Maneuver Autopilot

A new flight-test technique using a maneuver autopilot is being applied at the Dryden Flight Research Facility of the NASA Ames Research Center. The flight test maneuver autopilot (FTMAP) is designed to provide precise, repeatable control of an aircraft during certain prescribed maneuvers so that a large quantity of high-quality test data can be obtained with minimum flight time. The FTMAP can be used for various maneuvers, including level accelerations and decelerations, windup turns, and pushover/pull-ups. The FTMAP technique applies the type of automatic, closed-loop guidance and control required to expeditiously and accurately flight

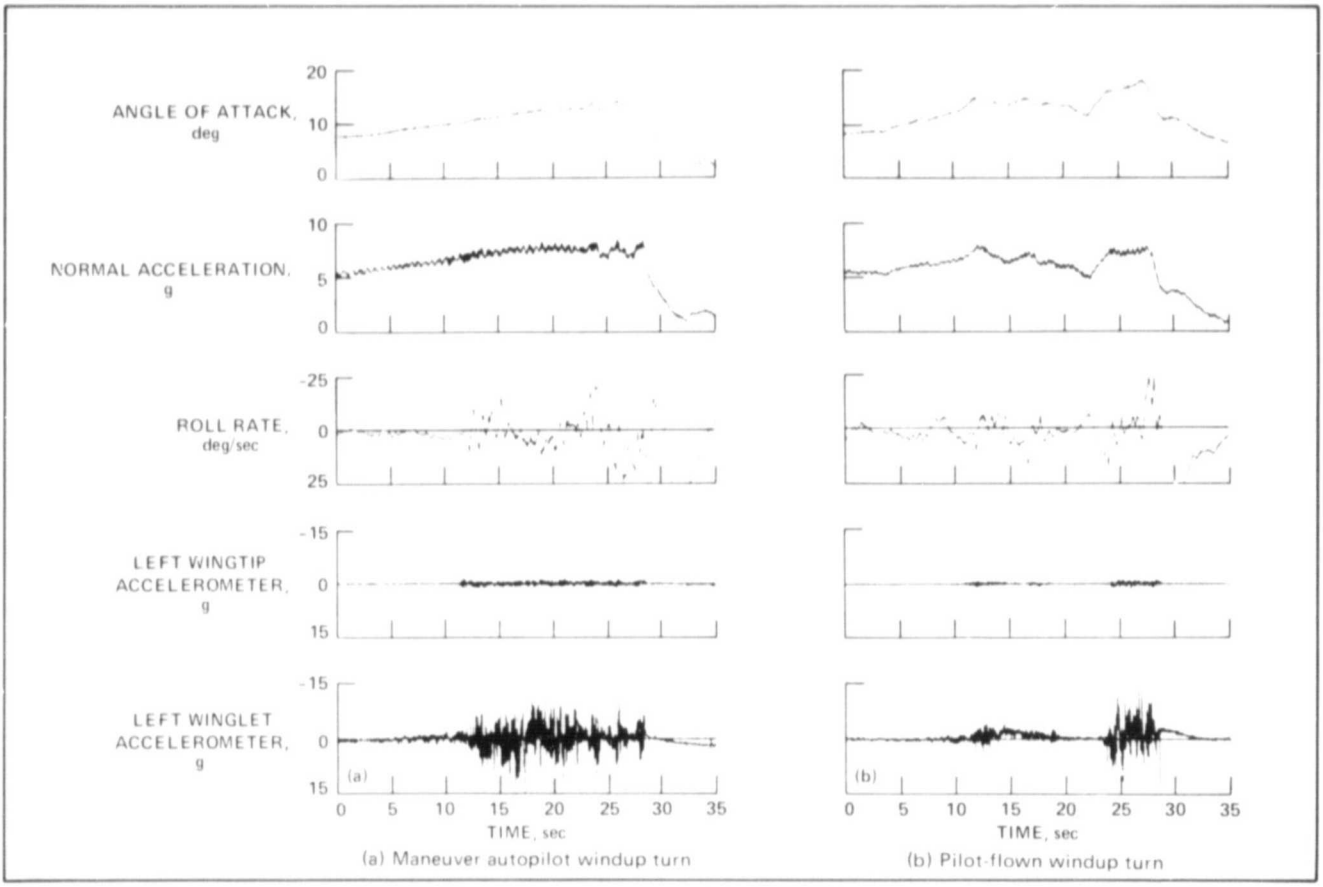
test the emerging generation of high-performance aircraft.

The FTMAP is an outer-loop controller whose outputs replace the normal pilot stick and throttle commands to the control system. Designed to control the aircraft to tolerances of ±0.5° angle of attack or ±0.5 g normal acceleration, ±0.01 Mach number, and ±500 ft altitude, the FTMAP is used as a flight-test tool for gathering aerodynamic, structural, flutter, and overall vehicle performance data. An extension of previous flight-test trajectory guidance research at Dryden, the FTMAP is the first closed-loop application of this pilot-aiding technique. The FTMAP was developed for the highly maneuverable aircraft technology (HiMAT), remotely piloted research vehicle (RPRV) to reduce pilot workload and to maximize the data collected from each flight.

The performance of the FTMAP during an elevated load factor windup turn is compared with a pilot-flown maneuver at the same flight condition. The improvements provided by the FTMAP are apparent: the FTMAP maneuver is steadier and smoother than the pilot-flown maneuver. The onset of buffet and the wing rock is unclear in the pilot-flown maneuver but clearly distinct in the FTMAP maneuver.

The FTMAP can provide precise, repeatable control of an aircraft during certain prescribed maneuvers so that a large quantity of high-quality test data can be collected with minimum flight time. Not only does the FTMAP represent a powerful pilot aid in the simultaneous control of multiple parameters to exacting tolerances; it also greatly reduces pilot workload. Although designed for a high-performance RPRV, the FTMAP represents a generic approach to flight-test flight research applicable to all classes of aircraft.

(E. Duke, Dryden Ext. 357)



(a) Maneuver autopilot windup turn (b) Pilot-flown windup turn

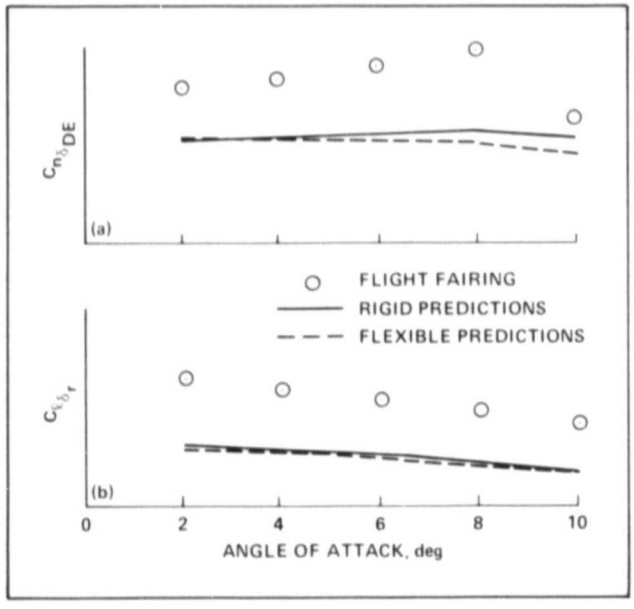
Comparison of FTMAP and piloted windup turn at 25,000 ft and Mach 0.90

Parameter Estimation

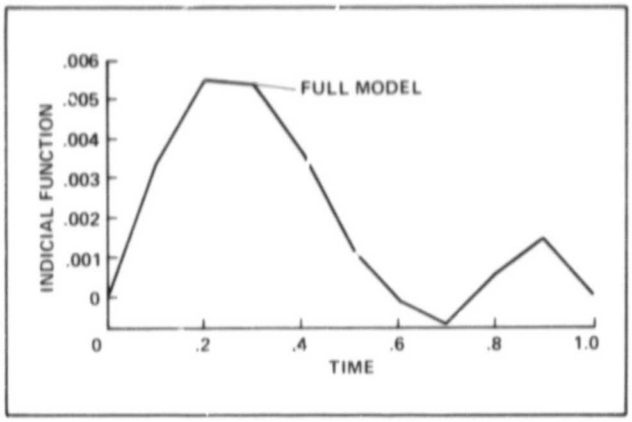
Parameter estimation is a generic field that involves several different disciplines and projects. Much of the parameter estimation work at Dryden in the past year has been in support of the Shuttle program with investigations principally associated with modeling in the hypersonic flight regime. Special models for reaction-control jet effectiveness using parameter estimation methods were developed to investigate predicted nonlinearities that were difficult to observe in flight. Significant differences were noted between predicted aerodynamic data and flight-derived data using parameter estimation. Extremely small maneuvers required that gyroscopic cross-coupling and instrument misalignments be investigated and thus were accounted for in the method used to analyze the flight-derived data. Results from the HiMAT flight program also showed significant differences between predicted data and flight-derived data obtained by parameter estimation. The flight-derived data, probably for the first time, were used to develop a completely new simulation data base.

In the high angle-of-attack regions, parameter estimation research has proven to be an encouraging tool because the nonlinear modeling problem can now be addressed. Neither linear nor nonlinear aerodynamic models are adequate in this high angle-of-attack region. Programs have now been developed that are capable of handling indicial function representations described as the aerodynamic responses of an aircraft to arbitrary inputs. Initial results reported in a paper by Iliff and Cupta are very encouraging.

(R. Maine, Dryden Ext. 724)



HiMAT program; (a) predicted data; (b) flight derived data



Flight estimated indicial function

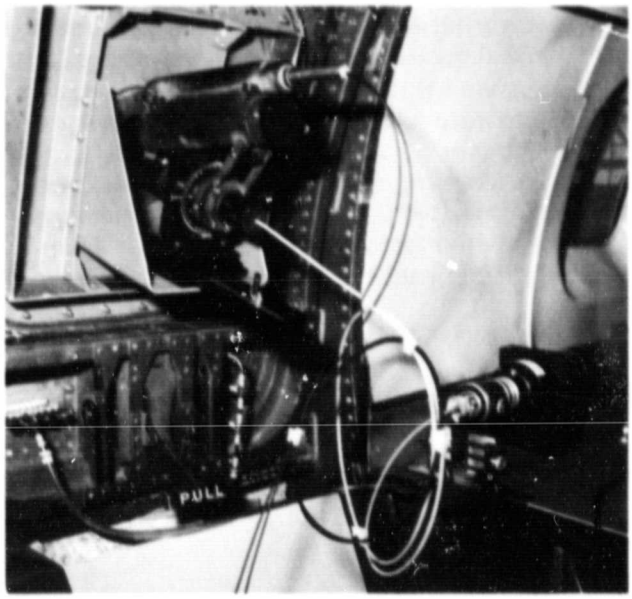
Laser Applications to Flight Testing

The objective of this study was to obtain experience in using optical tools to measure fluid-flow parameters in flight. Present methods of obtaining such information depend on direct-contact instrumentation which perturbs the flow being measured and often cannot be used in regions of hostile flow. A laser transit velocimeter developed by the Boeing Commercial Airplane Company has been tested on the Dryden JetStar airplane to determine some of the problems of using such devices in a flight environment.

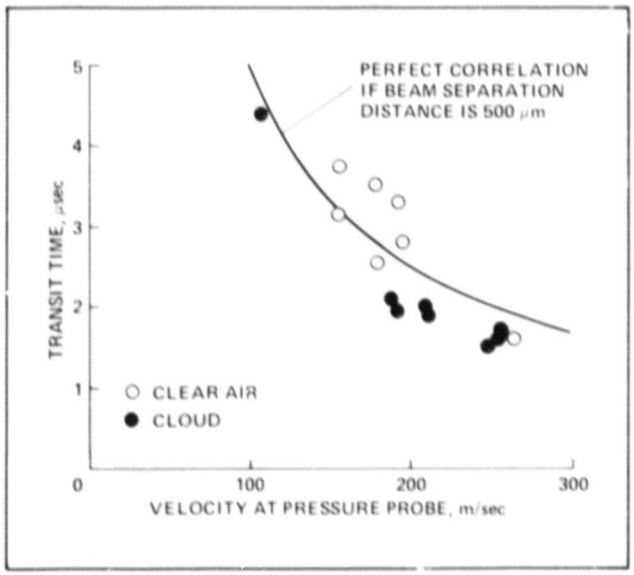
The device was operated at altitudes up to 30,000 ft and under a variety of atmospheric conditions. The transit times of natural atmospheric particles embedded in the flow-field passing between two beams of focused laser light were measured. If the device were calibrated in a known flow, the beam separation distance could be determined and hence, the transit times could be used to indicate velocity. Problem areas which were identified include background light interference and low concentrations of aerosols in the

atmosphere. One flight was made at night to eliminate background light and clouds were used to increase the aerosol concentration.

Laser measurements were compared with conventional velocity measurements and the line of perfect correlation for a given beam separation is shown. Deviations from this trend may be due to local flow turbulence which causes a statistical bias in the laser measurements.



Laser velocimeter installed in Jet Star



Comparison of laser velocimeter and pressure-probe measurements

This experiment has helped to evaluate the potential benefits of laser applications to flight testing. The problems which were encountered can be the basis of further research. Practical in-house experience with laser hardware has also been obtained from this experiment.

(R. Curry, Dryden Ext. 534)

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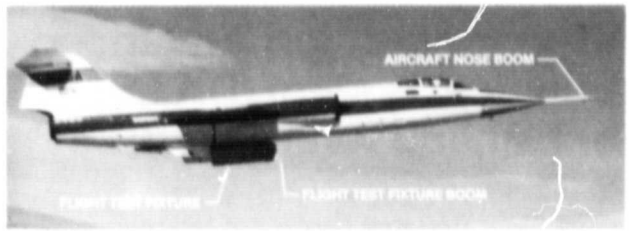
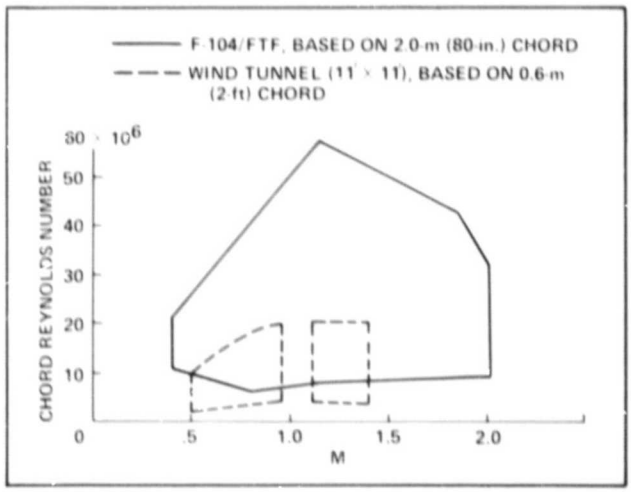
F-104/Flight Test Fixture

The Ames Dryden Flight Research Facility has developed a unique research facility for conducting aerodynamic and fluid-mechanics experiments in flight. A low-aspect-ratio fin, referred to as the Flight Test Fixture (FTF), is mounted on the underside of the fuselage of an F-104G aircraft. The FTF has a chord of 80 in. and a semispan of



F-104 with flight test fixture



Mach-Reynolds number envelope, chord Reynolds number

24 in. The facility capabilities include: (1) a large Mach-number envelope (0.4 to 2.0), including the region through Mach 1.0; (2) the potential ability to test articles larger than those that can be tested in wind tunnels; (3) the large chord Reynolds-number envelope (greater than 40×10^6); and (4) the ability to define small increments in friction drag between two test surfaces.

A report on the facility has been written, which discusses the following areas: (1) facility description, capabilities, and past and proposed users; (2) the operating envelope in terms of Mach number, dynamic pressure, and Reynolds number; and (3) the flow environment, such as chordwise pressure distributions, boundary-layer characteristics, and tuft photographs. Facility documentation is complete and the facility is considered operational.

(R. Meyer, Dryden Ext. 379)

A Demonstration Advanced Avionics System (DAAS) for General Aviation

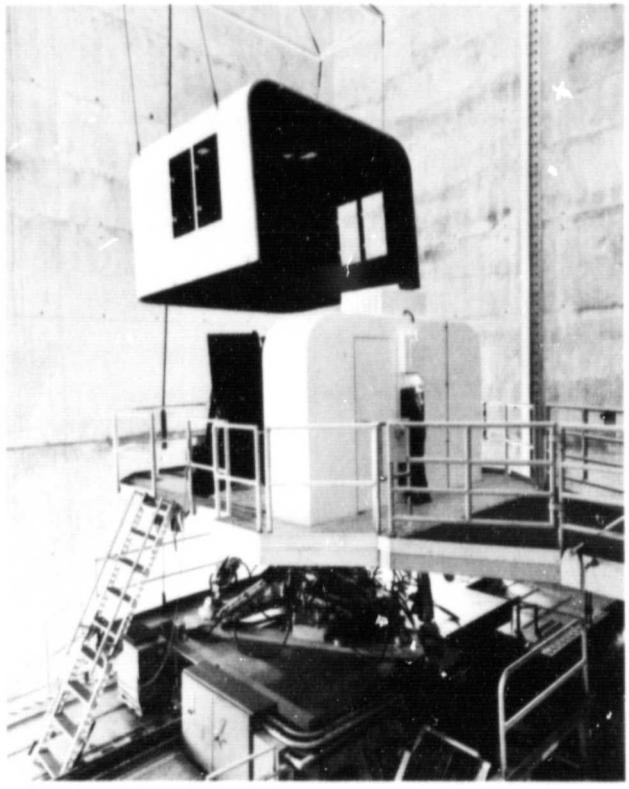
The Ames Research Center has recently completed a program which led to the development and flight evaluation in a Cessna 402-B of a fully integrated, microprocessor-based, digital avionics system referred to as DAAS. The program was initiated in 1975 in anticipation of an increasing dependence by general aviation on avionics and the supposition that the corresponding increase in their cost and complexity could potentially be offset by the introduction of fully integrated systems. The program objective was to provide information required for the design of reliable integrated avionics that would enhance the utility and safety of general aviation at a cost commensurate with the general aviation market.

DAAS integrates most general aviation contemporary and projected avionic requirements into a single system. It includes the basic flight control and navigation functions as well as more novel capabilities such as flight planning; computerized performance and weight and balance functions; stored checklists; engine and aircraft configuration monitoring and warning capabilities; built-in test; and a simulation mode for pilot training. The DAAS system utilizes a distributed microprocessor architecture with shared electronic displays, and a complete set of navigation and aircraft sensors. All processing, display, and sensor resources are interconnected by a standard bus to enhance overall system effectiveness, modularity, reliability, and maintainability.

(G. Callas, Ext. 5454)

DAAS panel installation

Vertical Motion Simulator



Vertical Motion Simulator

The vertical motion simulator (VMS) has been modified and is now in full operation with an interchangeable cab system. The interchangeable cab system permits the flexibility to reconfigure and check out new cab configurations in a fixed base area prior to placing the cab on the VMS. This permits shorter turnarounds between simulations.

The interchangeable cab system allows the cab to be turned 90°, depending on simulation requirements, to utilize the 40 ft of motion travel as either lateral motion or longitudinal motion.

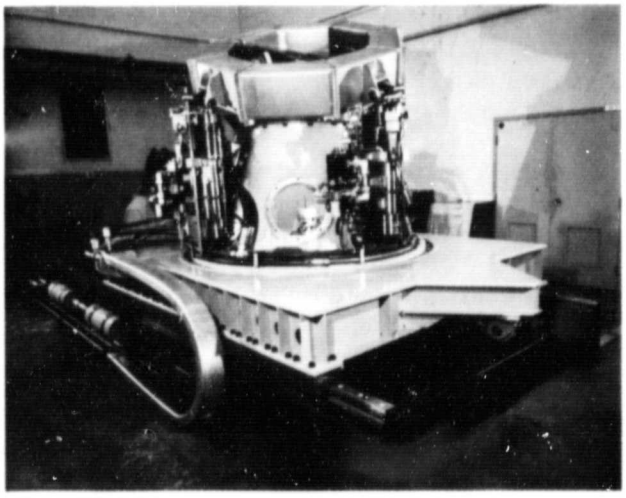
The interchangeable cab currently incorporates a four-window computer generated visual picture system with future cabs that will incorporate either straight-ahead collimating Redifon systems or computer-generated visual picture systems.

(A. Cook, Ext. 5162)

Rotorcraft Simulator

Under contract to Ames Research Center, Franklin Research Center has delivered a sophisticated four-degree-of-freedom motion generator for the Rotorcraft System Integration Simulator that will replace the existing motion system. This new unit, with its expanded performance and payload capability, was specifically designed to accommodate a wraparound, down-looking, wide-field-of-view visual system. The motion system is the first phase of an Army-sponsored, NASA-managed program to develop a high-fidelity rotorcraft simulation capability for government and industry research programs.

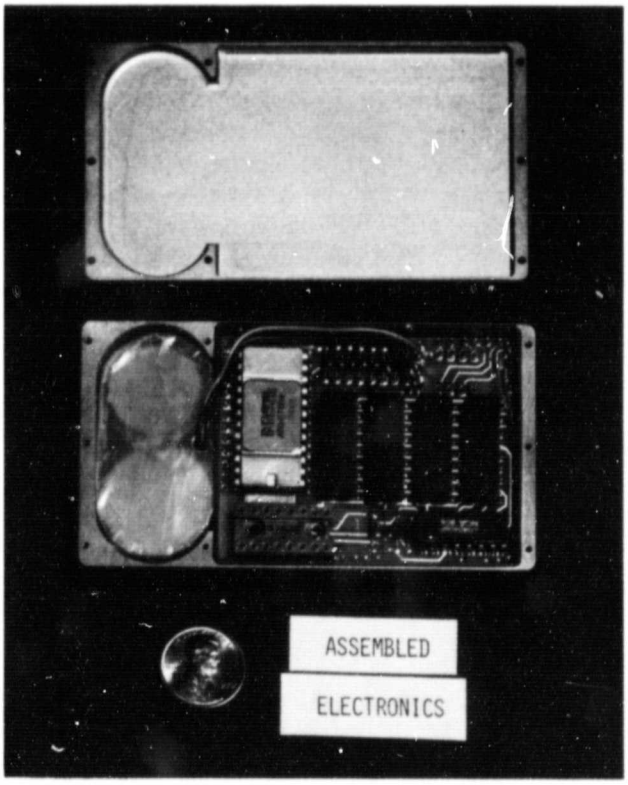
(R. Mancini, Ext. 6319)



Rotorcraft simulator motion generator

A Solid-state Digital Temperature Recorder

A solid-state, digital temperature recorder has been developed to be used in a joint U.S./U.S.S.R. Earth-oribtal biology mission and for experiments flown aboard STS 2, 3, and 4. It is a completely self-contained recorder and includes a temperature sensor; all necessary electronics for signal conditioning, processing, storing, control and timing; and a battery power supply. No electrical interfacing is required with the spacecraft or any other system using the unit. The recorder is small (9.5 by 5.4 by 1.6 cm^3), light and sturdy, and has no moving parts. It uses only biocompatible materials, so it is useful in conjunction with biomedical experiments, and it has passed vibration and shock spaceflight qualification tests. The unit is capable of storing 2048, -20° to +50° C (or any selected range within this span), 8-bit temperature measurements taken at intervals selectable by factors of 2 up to 240 min. Data can be retained for at least 6 months. The basic recorder can be modified to accommodate a variety of applications by adding memory to record more data, by



Solid-state, digital temperature recorder

changing the sensor to permit measurements other than temperature, and by using higher-capacity batteries to obtain longer operating periods.

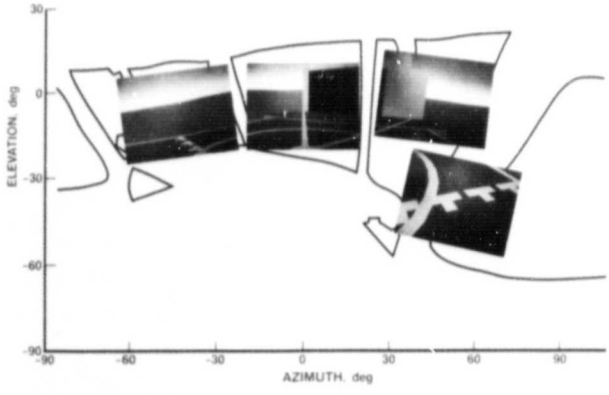
(G. Deboo, Ext. 5476)

All-weather Shipboard Operations

The first simulation on the Vertical Motion Simulator with the newly commissioned interchangeable cab and four-window, computer-generated-imagery visual system was completed. The objective of the simulation was the evaluation of various flight-control and display concepts for use in helicopter all-weather shipboard operations A Kaman SH-2F helicopter operating in the ship-landing environment of a Spruance-class destroyer was simulated. Six different hovering flight-control law concepts of varying complexity and both head-up and helmet-mounted displays were evaluated. Pilots from NASA and the Navy participated in the evaluation.

The simulation results indicated that the ship air-wake turbulence was the most significant environmental variable affecting hover performance. In addition, to achieve at least adequate pilot performance, attitude command-control compensation was required regardless of the display used. For improved performance with reduced pilot effort, a velocity-command, position-hold control system was desired. For the ship-landing task, the pilots found that looking out of the cockpit was indispensable. Of the two displays that allowed them to maintain an out-the-window view, the pilots preferred the head-up display to the helmet-mounted display.

(C. Paulk, Ext. 5440)



Destroyer CGI data base viewed from SH-2F ICAB

Rotorcraft Systems Integration Simulator

The Rotorcraft Systems Integration Simulator (RSIS) is an advanced simulator which will provide significantly improved capabilities over existing facilities to support rotorcraft research and development. It is under development in a joint program with the Army Aeromechanics Laboratory. The major components of the system are:

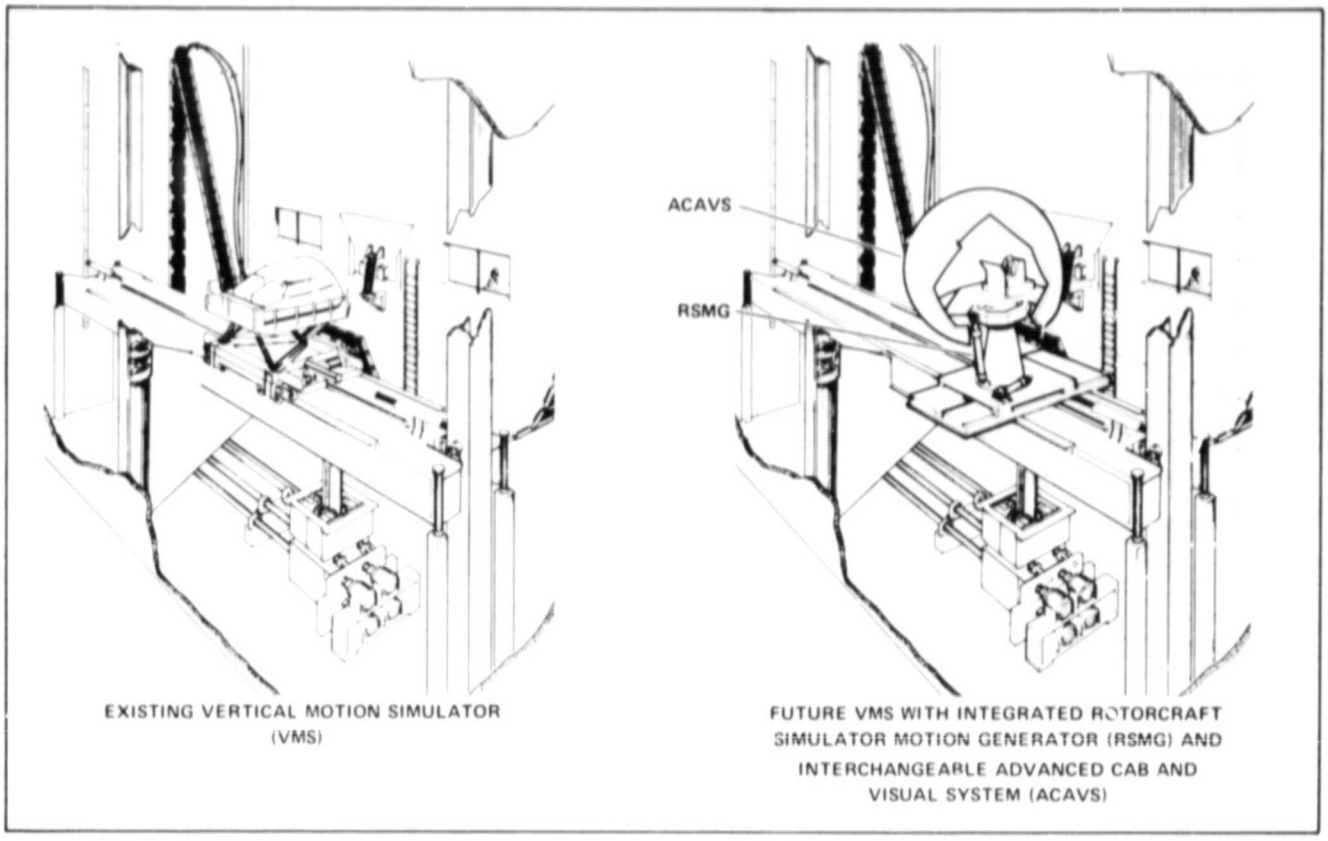
1. The Rotorcraft Simulator Motion Generator (RSMG), a high-performance, four-degree-of-freedom (longitudinal, roll, pitch, and yaw) motion generator designed and fabricated by Franklin Research Center. The RSMG will permanently replace the hexapod motion platform currently mounted on the Vertical Motion Simulator (VMS).

2. An advanced visual system which will feature high resolution and a large field of view. The image representing the pilot's out-the-window scene will be generated by a customized Evans and Sutherland CT-5 computer image generator. The display will be projected on a 20.5-ft-diam spherical screen by three General Electric single-gun, color TV, light-valve projectors and an optical system designed and fabricated by Farrand Optical Company.

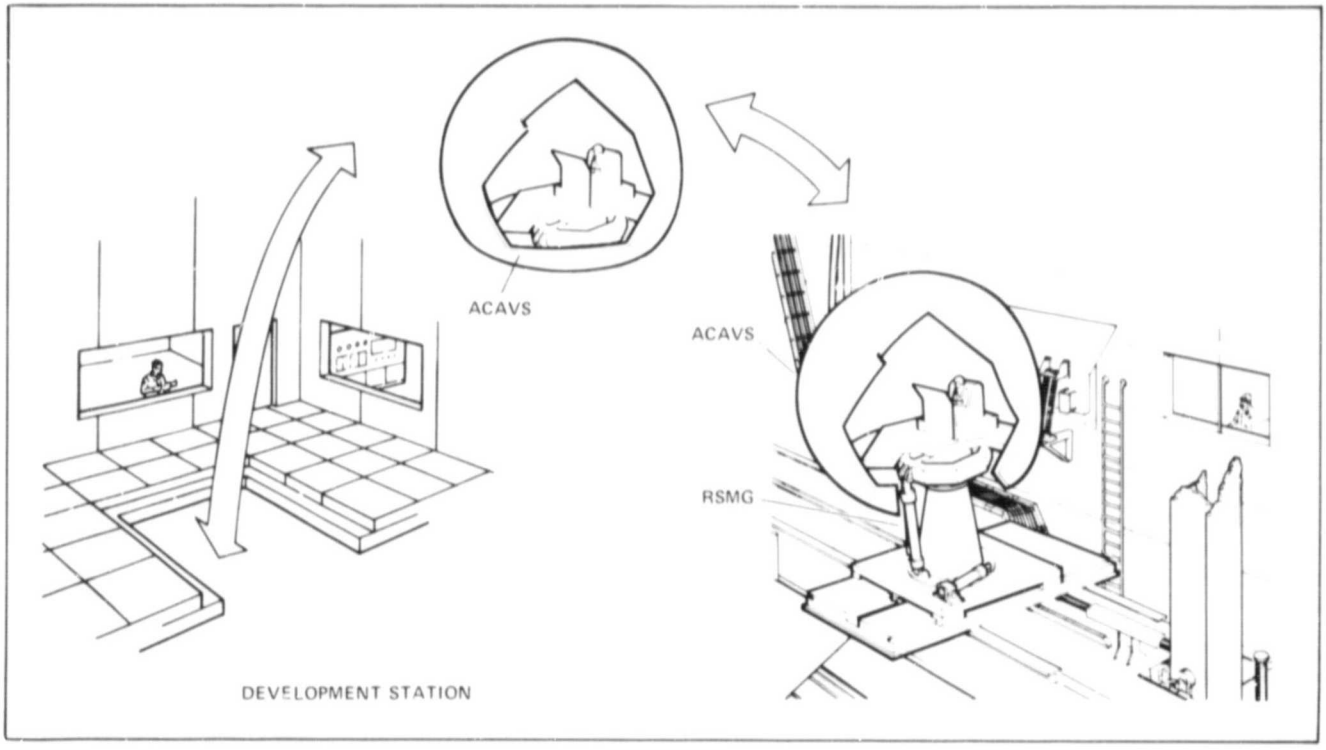
3. A generic rotorcraft cab which will be capable of simulating a wide variety of rotorcraft cockpits and crew-station arrangements.

4. A development station which will provide support equipment and facilities for cab reconfiguration and checkout.

The latter three items in combination are called the Advanced Cab and Visual System (ACAVS). The ACAVS can be relocated between the development station and the VMS in a manner similar to existing interchangeable cabs.



The Vertical Motion Simulator: RSIS Project overview



Final RSIS system

Two major project milestones were achieved in 1982. A contract was awarded to American Airlines for the final design and fabrication of ACAVS and its integration with the RSMG, and the RSMG was delivered to Ames and installed in a temporary location in preparation for final checkout and acceptance.

(A. Cook, Ext. 5162)

A Digital Flight-control System Verification Laboratory

As a part of a Joint NASA/FAA program, a laboratory has been established which supports a wide range of research activities in the area of verification and validation of Digital Flight Control Systems (DFCS). The laboratory is composed of numerous computers, including a redundant, reconfigurable DFCS representative of the current technology, to be used as a test bed for the experiments; it integrates a comprehensive set of advanced static and dynamic software verification tools and provides a friendly interface to all the available resources which is tailored to the requirements of control engineers The laboratory also includes capabilities for inserting a wide variety of hardware- and system-based faults.

The objectives and capabilities of the Verification Laboratory are oriented toward analyzing and enhancing the verification technology applicable to near-term DFCS configurations. The research activities being carried out in the laboratory include the quantitative analysis and enhancement of the overall effectiveness of the existing software test tools and of promising hardware verification technology.

Digital flight control system verification laboratory

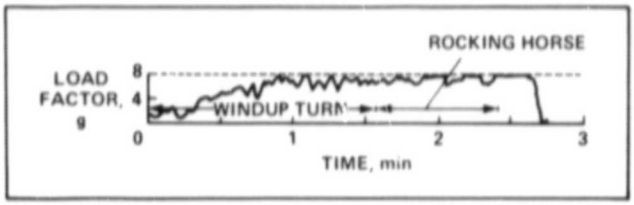
(P. De Feo, Ext. 5048)

Highly Maneuverable Aircraft Technology (HiMAT) Flight-test Program

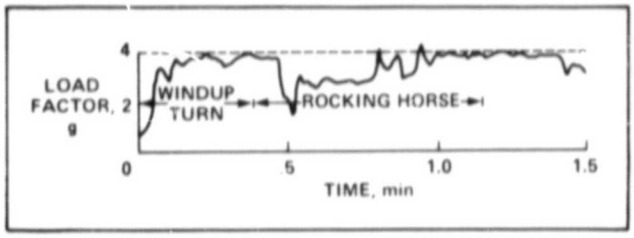
Several major accomplishments were made on the HiMAT Flight-Test program in FY 1982. The most significant was the successful completion of the program on July 30, 1982, 2 months ahead of schedule. This program consisted of three segments: (1) the demonstration of the design of the HiMAT vehicle in transonic maneuvering flight; (2) the demonstration of the design supersonic performance of the vehicle; and (3) the collection of "high-g" maneuvering flight-research data for various aeronautical disciplines.

For the transonic maneuvering demonstration, flight data were obtained to document the actual vehicle sustained turning capability at the design flight condition. The flight data were generated using a windup turn and rocking-horse maneuver at load factors near the vehicle design load factor of 8 g at Mach 0.9 and an altitude of 25,000 ft. This is almost twice the sustained turning capability of current fighters such as the F-15 and F-16. The maneuver was almost 3 min in duration, and load factor levels near 8 g were held for over 1-1/2 min. From this maneuver, the sustained turning capability for the HiMAT vehicle was established. The results showed the vehicle performance to be very near the design goal.

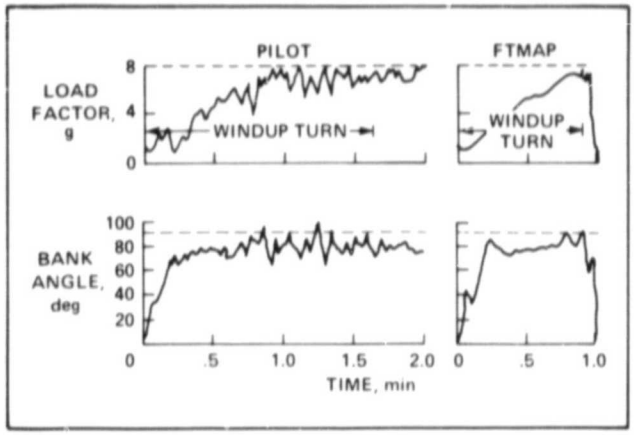
For the supersonic-performance demonstration, flight data to document the supersonic endurance and sustained g capability of the vehicle were obtained at Mach 1.4 at an altitude of 40,000 ft. A windup turn and rocking-horse maneuver along with acceleration/deceleration and cruise flight data were used to establish the vehicle performance at supersonic speeds. Load factors near 4 g were sustained at the supersonic-design flight conditions. Results from these and



Maneuver demonstration time history; Mach number 0.9, altitude 25,000 ft



Supersonic performance demonstration time history; Mach number 1.4, altitude 40,000 ft



Comparison of a pilot and FTMAP flown high-g turn; Mach number 0.9, altitude 25,000 ft

other maneuvers showed that the HiMAT vehicle significantly surpassed the design endurance and sustained turn capability at the supersonic design Mach number of 1.4.

The third segment of the HiMAT flight-test program was to collect "high-g" flight research data in disciplinary areas of structure, flutter, aircraft performance, propulsion, stability and control, and buffet. These data were collected in four flights by using a Flight Test Maneuvering Auto Pilot (FTMAP) which was designed to approach wind-tunnel-type precision in holding flight conditions through load factors from 0 to 9 g. Not only was the maneuver performed in a shorter time by the FTMAP, but it was also performed in a much smoother manner. Very high quality data have been collected with the FTMAP, reducing the number of maneuvers and repeats from that originally planned.

(H. Arnaiz, Dryden Ext. 770)

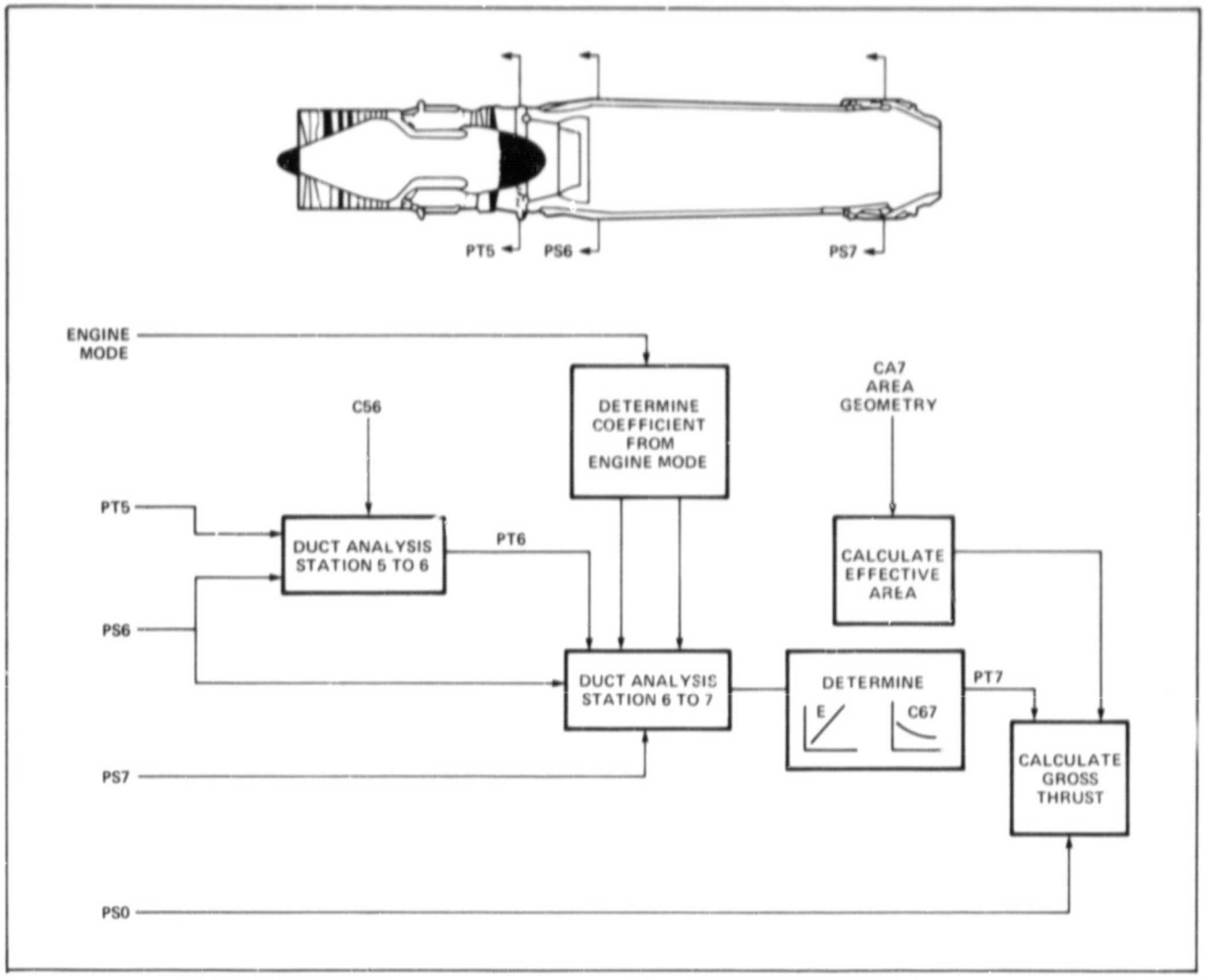
Simplified Gross-thrust Calculation Method

In support of the Highly Maneuverable Aircraft Technology (HiMAT) program, a simplified gross-thrust calculation method was developed for the J85-21 afterburning turbojet engine. The method was evaluated in an altitude facility to determine the accuracy of the method and the effects of different engine operating modes, and to generate calibration information on that accuracy. The method had been developed and evaluated on other engine configurations and was less complex than the traditional gas generator methods while retaining good accuracy.

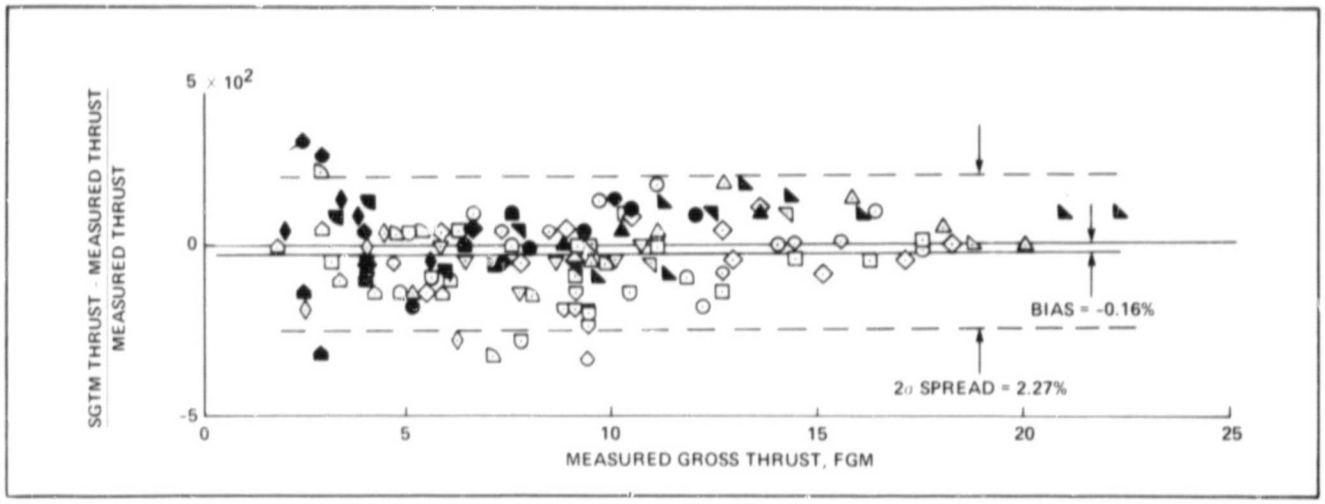
The HiMAT vehicle is a remotely piloted research vehicle. The propulsion system is a digitally controlled J85-21 engine capable of standard and nonstandard engine operating modes. The nonstandard engine mode capability, along with limited vehicle instrumentation and the desire to have the ability for computing gross thrust in real time, precluded the use of traditional gas-generator methods for gross-thrust calculations.

The Simplified Gross-Thrust Method (SGTM) uses tail-pipe pressure data from the engine and ambient pressure data to predict the gross thrust. The algorithm of the method is based on the one-dimensional analysis of the flow in the afterburner and nozzle sections of the engine. The algorithm contains calibration coefficients which account for the model errors as a result of the assumptions made in the method. These coefficients are determined through an iterative process using actual thrust data to minimize the thrust error.

The SGTM thrust predictions were compared to the facility-measured gross thrust, and the accuracy of the method was determined. The comparison was made for each of the resultant algorithms generated from different calibration



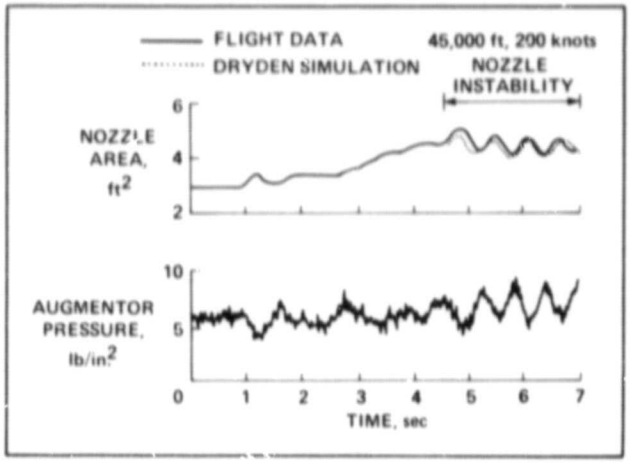
Schematic of the SGTM algorithm and engine instrumentation



Thrust prediction on standard and open mode data using calibration 1

information. The total accuracy values for the different calibrated algorithms ranged from 1.88% to 3.36%. The method was found to be a feasible means of computing the gross thrust of the HiMAT engines. The accuracy of the method was dependent on the calibration information used and the repeatability of the pressure measurements. The optimum algorithm was one which was tailored to the engine operating mode and the flight conditions where the engine would be operating.

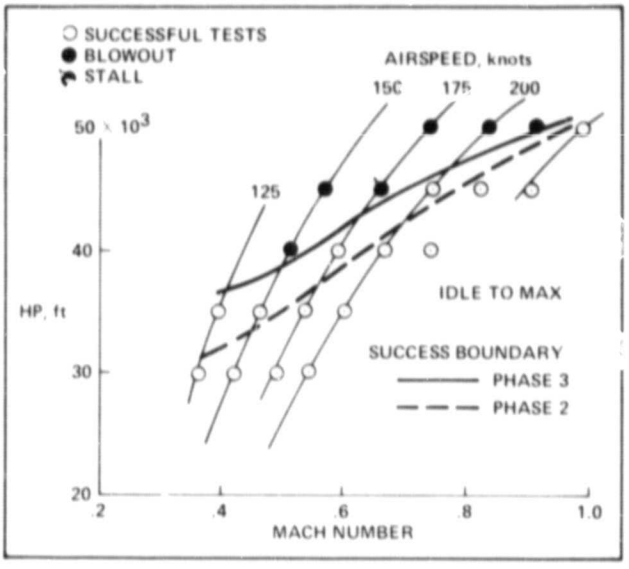
(J. Baer-Riedhart, Dryden Ext. 336)



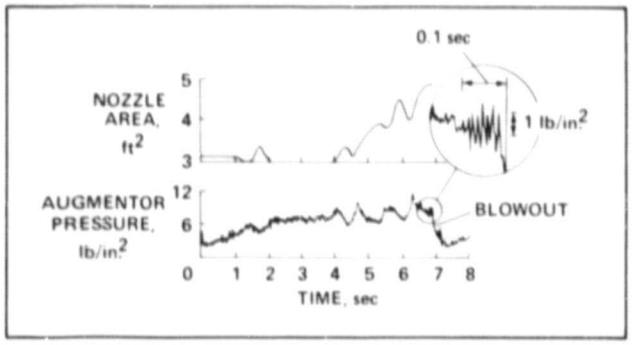
Time history of an idle-to-maximum power throttle transient showing a nozzle instability

Digital Electronic Engine Control

A full-authority digital electronic engine control (DEEC) system on an F100 turbofan engine is being evaluated in an F-15 airplane. The DEEC is a single-string digital control system with selected input-output redundancy and an integral hydromechanical backup control. Previous results had validated the no-trim concept and demonstrated an improved air-start capability. In FY 1982, the DEEC augmentor performance and backup control operation were investigated. With Phase 2 software, augmentor blowouts and stalls were encountered at high altitudes and low Mach numbers. High-frequency-response pressure data showed that some augmentor blowouts were caused by rumble, an acoustic-combustion coupling phenomenon that occurs with overly rich



Comparison of DEEC Phase 2 and Phase 3 idle-to-maximum power throttle transient capability



Time history of an idle-to-maximum power throttle transient showing a rumble induced augmentor blowout

fuel-air ratios. Also encountered was an augmentor instability which caused blowouts and stalls. Previous engine-simulation testing and altitude-facility testing of the same flight engine had not predicted the observed instability. Specific engine testing at NASA Lewis identified an instability only when the nozzle loop gain was doubled. A nonlinear digital simulation of the nozzle loop was developed at Dryden and closely matched the instability observed in-flight. The discrepancy between earlier simulation results and the flight results was probably due to inadequate modeling of the engine characteristics. The lack of agreement between the altitude-facility tests and flight tests was partially

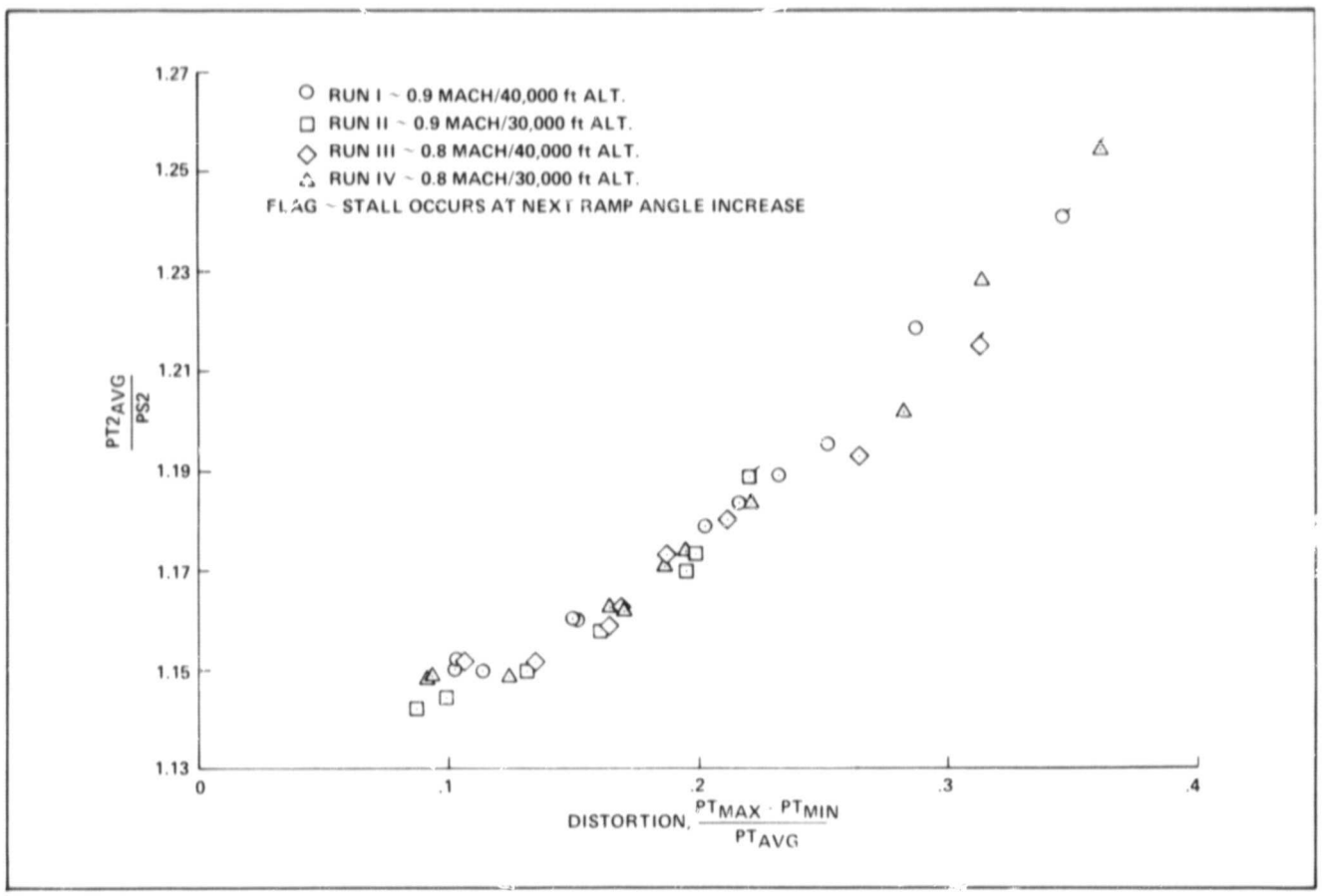
due to inadequate modeling of the engine characteristics. The lack of agreement between the altitude-facility tests and flight tests was partially due to the inability of the altitude facility to duplicate flight conditions for throttle transients.

Based on an analysis of the Phase 2 software flight results, logic changes were implemented to eliminate the nozzle instability and the augmentor rumble. This logic was recently flown in Phase 3 of the DEEC evaluation. Improvements in the idle-to-maximum power rapid-throttle transient capability, due to the software changes, are shown in the third figure. The increase in altitude capability is 3,000-5,000 ft.

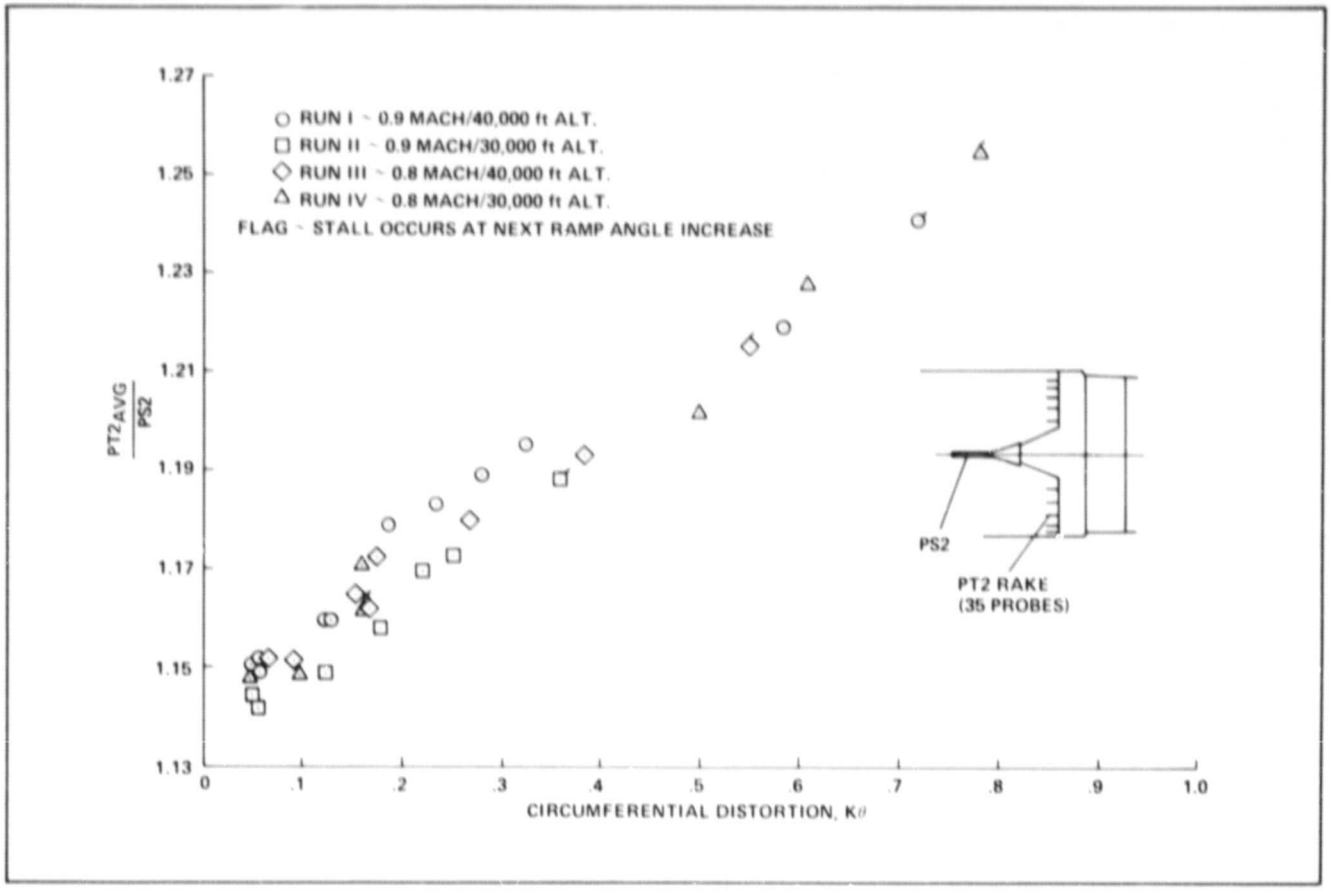
(L. Meyers, Dryden Ext. 501)

Engine Inlet Static Pressure Correlation With Inlet Distortion

Flight-test results of an engine inlet static (PS2) nose boom on an F100 engine in an F-15 airplane were reported in 1980. The purpose of the tests was to determine the potential of a new engine-control parameter which uses the single static pressure measurement. These tests determined that the new PS2 engine-control parameter provided a predictable measure of total pressure (PT2) as a function of airflow for low-distortion



Pressure ratio versus distortion for inlet ramp excursions



Pressure ratio versus distortion for inlet ramp excursions resulting in engine stalls

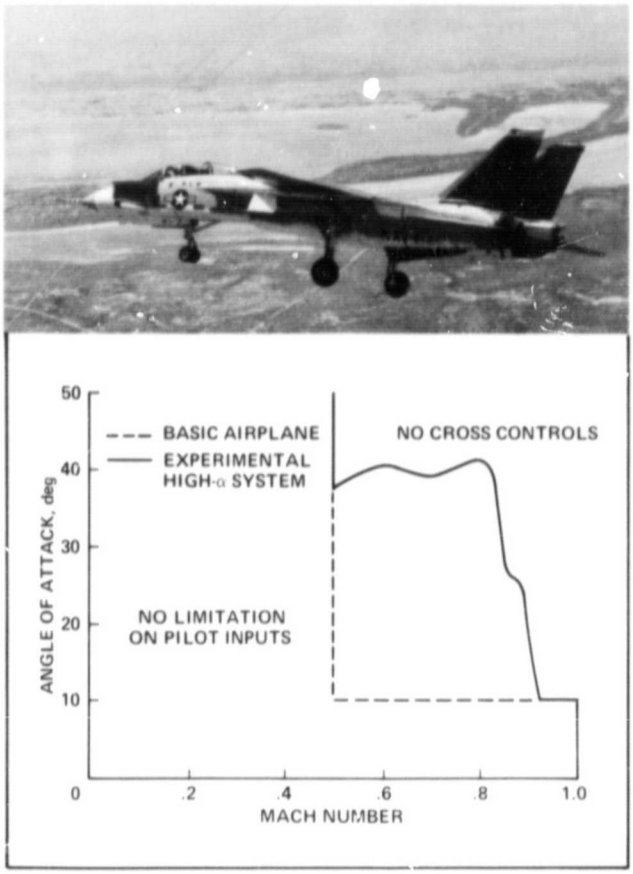
inlet conditions. Although the ratio of total pressure to static pressure at the compressor face (PT2/PS2) when plotted against distortion showed considerable scatter during the original analysis, further analysis produced good correlation with all of the distortion descriptors.

Distortion of the inlet airflow was obtained by the off-schedule operation of the F-15 inlet third ramp angle with constant throttle at steady-state flight conditions. The data from four separate ramp excursions that resulted in engine stalls are presented. The distortion was predominantly circumferential, and the circumferential distortion parameter, $K\theta$, as well as the max-min-over average, distortion descriptor showed good correlation when compared with PT2/PS2. This characteristic establishes the capability of the PS2 probe to provide an automatic compensation for distortion when used as an engine control parameter.

(D. Hughes, Dryden Ext. 152)

Flight Investigation of High-angle-of-attack Control Techniques On the F-14 Airplane

Improved handling qualities of fighter aircraft can be provided by various stability and control augmentation techniques. NASA Langley, NASA Ames, and the Navy have conducted a joint flight demonstration of these techniques on an F-14 airplane. An experimental lateral-directional stability and control system has been evaluated throughout the subsonic flight envelope of the F-14. The test results show that high-α handling qualities problems, such as wing rock, roll reversal, and directional divergence, can be suppressed or completely eliminated by appropriate gain schedules, feedbacks, and cross-feeds in the control system. Open-loop tasks, such as inten-



Departure resistance improvement due to the experimental high-α control system

tionally misapplied controls and closed-loop air-to-air tracking were used to investigate the high-angle-of-attack characteristics of the augmented airplane.

Throughout the flight evaluation, simulation played a significant role. After refining the aerodynamic data base with the initial flight-test results, the simulator was used in planning flights and formulating test techniques to reduce the inherent hazards of flight testing at high angles of attack.

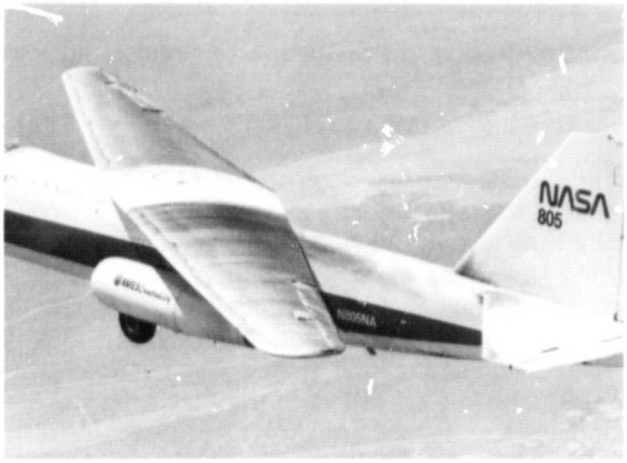
(J. Gera, Dryden Ext. 617)

AD-1 Oblique Wing Research Aircraft

Seventeen pilots flew the AD-1 Oblique Wing Research Aircraft. Of the 17 pilots, 8 were from Dryden Flight Research Facility, 2 from Ames Research Center, 2 from Langley Research Center, 3 from the Air Force Flight Test Center, and 2 from the Naval Air Test Center. Each pilot flew for about an hour to assess the handling qualities and evaluate a standard set of maneuvers. Pilot evaluations were documented and are available for further study.

The evaluation consensus was that, up to an approximate 45° sweep angle, the aircraft was relatively easy to maintain on a steady heading, zero sideslip, and constant airspeed. Pilot ratings were 1 to 3 on the Cooper-Harper rating scale of 1 to 10 (1 is excellent and 10 is uncontrollable at some portion of the flight). Pilot ratings of 4 to 7 were given with the wings between a 45° and 60° sweep angle.

Oil pigmentation techniques were evaluated on the AD-1 wing by placing various mixtures of



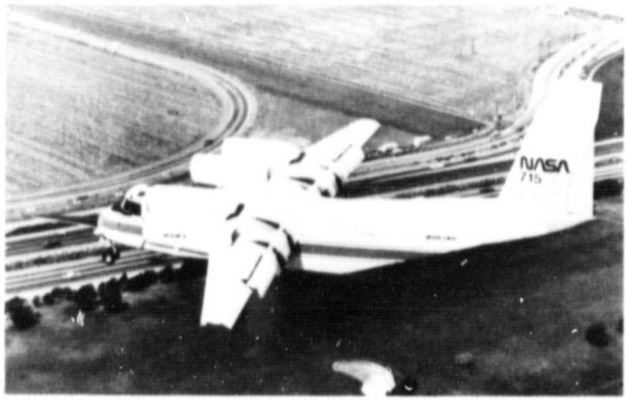
Oil flow on top wing surface of AD-1

darkened motor oil directly on the wing to determine which were most suitable for flow visualization. Of the four blends evaluated, two mixtures of oil and putty black provided adequate visualization to assess natural laminar flow and transition characteristics. These oil flow patterns were photographed from a chase plane and then analyzed for flow characteristics. This technique eliminates the use of a complex oil dispensing system.

The AD-1 Oblique Wing Research Aircraft was taken to Oshkosh, Wisconsin, for demonstration at the 30th Annual Experimental Aircraft Association Convention. It was flown each day from July 31 through August 7, 1982. Public interest was outstanding.

(W. Painter, Dryden Ext. 238)

Quiet Short-Haul Research Aircraft



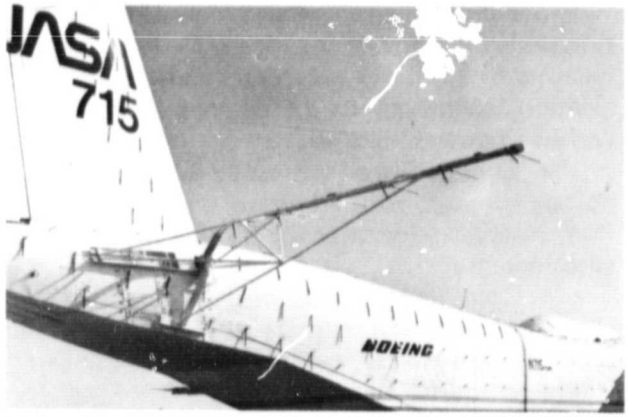
Quiet Short-Haul Research Aircraft in landing approach

Current high-performance STOL aircraft are configured with high "T" tails because of the powerful downwash from the high-lift flap system. Such configurations are undesirable for such applications as aircraft intended for operation from aircraft carriers, and for modification of existing aircraft such as the C-130.

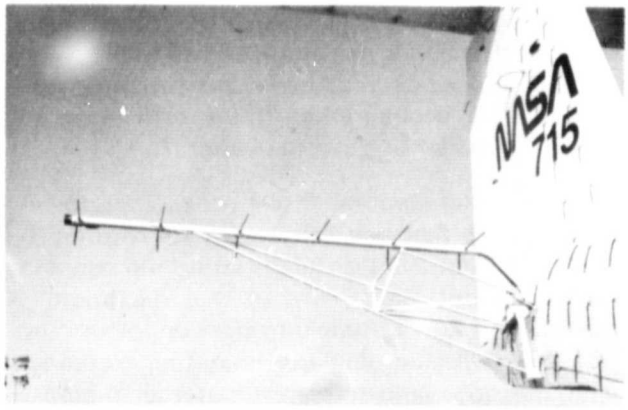
To determine whether low-mounted horizontal stabilizers could be used with high-performance, propulsive-lift aircraft and to determine the parameters for the design of such installations, an experimental program was conducted with the Quiet Short-Haul Research Aircraft (QSRA). The boom mounted on the aft fuselage of the QSRA has six probes equally spaced along its span. The span is the same as the semispan of the existing horizontal stabilizer. The probe pressure results, suitably reduced, provide the angle of flow in the vertical and the horizontal planes and the local dynamic pressure, in the location where a low mounted horizontal stabilizer would be mounted.

Measurements of the flow field were made in flight over the entire low-speed envelope of the QSRA. These included the full range of flap settings, power settings, angle of attack, and sideslip angle. These data are being reduced. Preliminary results indicate that with sufficient trim authority, a low-mounted horizontal stabilizer can be made to function satisfactorily with a high-performance, propulsive-lift aircraft.

(F. Baker, Ext. 5559)



Downwash boom mounted on Quiet Short-Haul Research Aircraft aft fuselage



Spanwise location of sensor probes on downwash boom

Conference on Planning for Rotorcraft and Commuter Air Transportation

A major conference sponsored by NASA and the Transportation Planning Division of the American Planning Association was held in Monterey, California. It brought together for the first time a representative group of planners and public officials from all levels of government, and a select group of rotorcraft and commuter aircraft manufacturers, operators, and researchers to exchange viewpoints on planning for rotorcraft and commuter air transportation.

After an intensive series of presentations and working group meetings, several major points were resolved which should be adopted in a plan to improve air transportation. These included the following:

1. Developing an aggressive, new national aviation policy to provide the means for bringing the benefits of advanced rotorcraft and commuter aviation technology to the citizens of the U.S. within a reasonable time.

- Conducting an aggressive rotorcraft technology program with emphasis on noise reduction, safety, and economics by the government with industry.
- Continuing technology development by the government and industry to reduce noise, and improve ride quality, safety, and economics of future commuter aircraft.
- Demonstrating promising advanced-vehicle concepts which provide industry with sufficient confidence to put these concepts into operation.
- Reviewing and revising air traffic control procedures and other aspects of the National Airspace System on a continuing basis to provide additional discrete airspace for helicopter operations and to accommodate more efficiently all major categories of short-haul aircraft.

2. Planning comprehensive urban transportation systems that will fully integrate rotorcraft and commuter aviation plans with land use and other transportation plans so that maximum advantage is taken of air-transport opportunities.

- Developing and disseminating planning data, methods, and reference material to community planners as a cooperative effort between planners, operations, manufacturers, and researchers.
- Gaining public acceptance of rotorcraft and commuter air transportation through initiative efforts by industry working with planners and public officials.
- Improving working relations of FAA and planners with airport operators to develop and use flight procedures to minimize noise impacts on communities.
- Improving the planning by public officials and planners of land use controls on airport environs and facilitating the environmental review process.

3. Providing a continuing forum for planners and technologists to work toward the achievement of the Monterey Conference Resolutions.

(J. Zuk, Ext. 6568)

Fireworthy Aircraft Seat Systems

The purpose of this work is to examine the potential of fire-blocking mechanisms for aircraft seat cushions to provide an optimized seat configuration with maximum fire protection and minimum weight. Aluminized, thermally stable fabrics were found to provide adequate fire protection when used in conjunction with urethane foams, while maintaining minimum weight and being cost-effective.

Major accomplishments include: a complete model and computer-based algorithm developed to determine the cost/weight effectiveness of the foams and fire-blocking layers tested; a full-scale laboratory testing at Douglas Aircraft which proved to be a viable test methodology for comparing the fire resistance properties of aircraft seats; two convenient and accurate laboratory-based methods of measuring the fire resistance of seat cushions that were developed using small-scale testing; and mechanical testing that showed polyurethane-based aircraft seating to be the most desirable type of cushioning available, requiring, nevertheless, a fire-blocking layer.

(D. Kourtides, Ext. 5226)

Impact Resistance of Modified Epoxy Composites

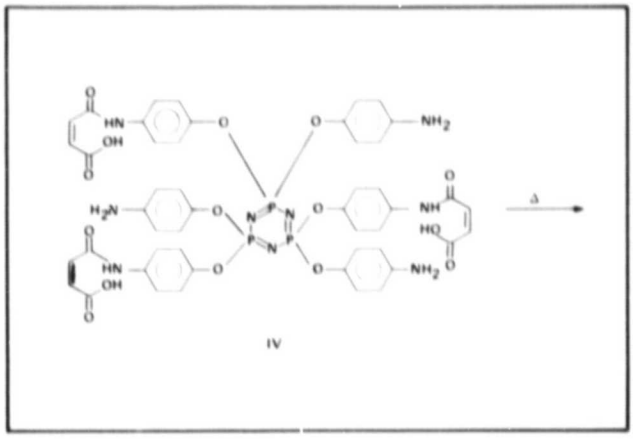
Composites made with commercially available epoxy resin systems were evaluated for impact resistance. The main resin was a trifunctional epoxy modified with a carboxy-terminated butadiene-acrylonitrile copolymer and a brominated epoxy resin at various concentrations. The composites were reinforced with a commercially available satin-weave carbon cloth. The impact resistance was determined by testing the shear strength of the composites after impact by a Gardner-Holt impact tester. The flexural strength and modulus at room temperature and 200° F, limited oxygen index, glass transition temperature, and thermogravimetric analysis were also determined. Modification of the resin improved the impact resistance.

(W. Gilwee, Ext. 6256)

Fire and Heat Resistant Laminating Resins

A novel class of flame- and heat-resistant polymers has been made by the thermal polymerization of maleimido-substituted aromatic cyclotriphosphazenes. The polymer (VI) obtained from precursor monomer (V) showed good thermal stability and is noteworthy for its high char yield (82% at 800° C in nitrogen and 80% at 700° C in air).

The monomer is synthesized by reacting the cyclic phosphonitrilic dichloride trimer with p-nitrophenol to give the hydrolytically stable hexakis-(4-nitrophenoxy)cyclotriphosphazene and reducing the nitro groups to the corresponding amines with hydrogen and platinum oxide. The amino compound is reacted partially with maleic anhydride in DMAC to give the monomer (V). In another reaction some of the amine groups were reacted with perfluorosuccinic anhydride.



IV

Thermal polymerization of maleimido-substituted aromatic cyclotriphosphazenes

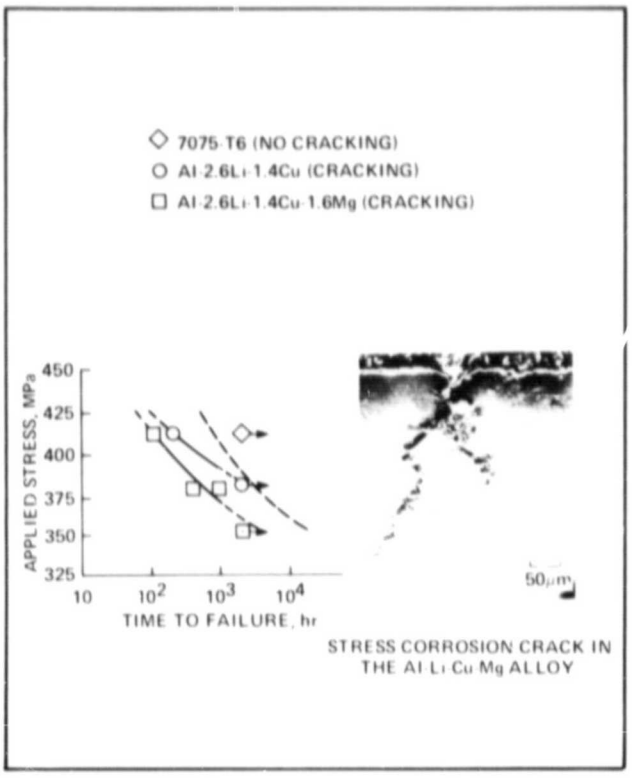
The structures of these cyclic phosphazene trimeric precursors and polymers were characterized using FT-IR, NMR, mass spectra, and ^{19}F-NMR. Also, ^{31}P "magic angle," spinning NMR of solid polymer (VI) (8.58 ppm), has led to the conclusion that the cyclotriphosphazene ring structure is preserved in the polymer. The curing behaviors of polymer precursors and thermal stabilities in the polymers were evaluated by differential scanning calorimetry and thermogravimetric analyses. Graphite fiber laminates were prepared.

(G. Fohlen, Ext. 5936)

Stress-corrosion Behavior of Advanced Aluminum Alloys

Advanced powder metallurgy (P/M) aluminum (Al) alloys containing small additions of lithium appear very attractive as future aerospace structural alloys because of their increased specific strength and stiffness. At present, the stress-corrosion behavior of high-strength Al alloys is a significant problem in the aircraft industry, and thus, the apparent advantages of the aluminum-lithium (Al-Li) alloys may have to be adjusted for their stress-corrosion behavior. Our research in advanced aluminum alloys is directed toward the development of this required understanding. We have for the first time demonstrated that these advanced Al-Li alloys are very susceptible to stress corrosion in salt water under the right conditions, and in fact, can be more susceptible than the presently used Al alloys. However, evidence suggests that this susceptibility is dependent upon the exact electrochemical conditions which exist in the environment and the specific microstructure of the alloy. Studies are continuing to better understand the electrochemistry of degradation and the influence of specific microstructural constituents. The latter is being investigated through the use of well characterized, mechanically alloyed Al-Li alloys.

(H. Nelson, Ext. 6137)



The relative stress-corrosion behavior of aluminum alloys in an aqueous 3.5% NaCl solution